Integrated Laboratory Systems

Triethylamine
[121-44-8]

Review of Toxicological Literature
(Update of July 1997 Review)

Prepared for

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EXECUTIVE SUMMARY

The nomination of triethylamine [121-44-8] is based on its high production volume, the large number of occupationally exposed workers, and the lack of carcinogenicity data.

Triethylamine is produced by Air Products and Chemicals Inc., Elf Atochem North America Inc., and Hoechst Celanese Corporation. It is produced by reacting ammonia with ethanol, *N*,*N*-diethylacetamide with lithium aluminum hydride, or ethyl chloride with ammonia under heat and pressure.

In 1995, 20 million pounds (9000 metric tons or Mg) of triethylamine were consumed in the U.S. The largest use of triethylamine (9 million pounds [4000 Mg]) was as a catalyst to cure the resin systems incorporated into sand cores for foundry molds. In addition, approximately 5 million pounds (2000 Mg) were used as a curing catalyst in phenol-formaldehyde particleboard adhesives; 2-3 million pounds (900-1300 Mg) were used for the precipitation and purification of penicillin and cephalosporin antibiotics; and 1-2 million pounds (500-900 Mg) were used for the production of polycarbonate resins. A wide variety of other uses account for minor consumption.

Triethylamine enters into the environment mainly via emissions and effluents released during its production and use. Triethylamine has also been detected, but not quantitated, in boiled beef. Occupational exposure occurs mainly via inhalation and dermal contact with the vapor. In a 1984 survey, NIOSH reported that 79,271 U.S. workers were exposed to triethylamine.

The toxicity of triethylamine in experimentally and occupationally exposed individuals has been evaluated. Severe visual disturbances and changes in electrical activity in the cerebral cortex have been detected in human volunteers exposed to triethylamine by inhalation. Occupationally-exposed workers have reported visual disturbances associated with exposure to triethylamine. Several case reports also indicate that exposure to triethylamine causes ocular and respiratory abnormalities.

The metabolism and excretion of triethylamine in humans following exposure by inhalation, ingestion, or intravenous (i.v.) injection is known. Triethylamine is excreted in urine largely unchanged, to a lesser extent as triethylamine-oxide (TEAO) and, in trace amounts, as diethylamine. The average plasma and urine half-lives for triethylamine were 3 to 4 hours.

From acute toxicity tests, the dermal LD_{50} for rabbits was 0.57-0.794 mL/kg (4.1-5.69 mmol/kg), while the inhalation LD_{50} for mice and rats was 6000 mg/m^3 (1425 ppm; 59.29 mmol/m^3) and 420-10,000 mg/m^3 (99.8-2375 ppm; 4.16-98.82 mmol/m^3), respectively. The intraperitoneal (i.p.) LD_{50} was 183-405 mg/kg (1.81-4.00 mmol/kg) for mice and the

oral LD_{50} was 450-1000 mg/kg (4.45-9.88 mmol/kg) for mice and rats, 1460 mg/kg (14.4 mmol/kg) for rabbits, and 730 mg/kg (7.21 mmol/kg) for cats.

In acute animal studies, triethylamine caused dermal and ocular irritation, and severe toxicity and death following inhalation or oral exposure. In short-term inhalation studies with rats, changes in the lungs, brain, and liver were detected following exposure for 3 months, while changes in the nervous system, hypohemoglobinemia, a rise in the number of reticulocytes in blood, and chronic inflammation of lungs were detected following exposure for 6 months. In rats, administration of triethylamine (60 mg/day; 0.59 mmol/day) by gavage for 6 weeks caused convulsions, with females exhibiting the more severe reaction. Mortality was present among female but not male rats. Oral administration of multiple doses of 1 or 10 mg/kg (0.01 or 0.10 mmol/kg) triethylamine to rats caused changes in conditioned reflexes (duration of exposure not provided). No adverse effects were observed in rats orally administered 54.5 mg/kg (0.540 mmol/kg) triethylamine daily for 2 months.

In short-term studies with rabbits, severe ocular irritation was observed following exposure to 50 ppm (210 mg/m^3) triethylamine for 30 days, while lung and eye irritation was observed at 50 and 100 ppm (210 or 414 mg/m^3) for 6 weeks. Exposure to 100 ppm also caused degeneration and inflammation in liver and kidneys which led to deterioration of heart muscle. Administration of 6 mg/kg (0.06 mmol/kg) triethylamine to rabbits caused a transient effect on hepatic carbohydrate metabolism. Administration of a lower dose (1 mg/kg; 0.010 mmol/kg) had no adverse effect.

Only limited data were available on the reproductive and teratogenic effects of triethylamine. In a three-generation reproductive study in which rats were administered triethylamine in drinking water, the only adverse effect observed was a slightly reduced average body weight in third-generation rats. The development of ova into normal blastocysts was disrupted by oral administration of triethylamine to pregnant rabbits during gestation days 1-3. The median effective dose (ED_{50}) for embryotoxicity in 3-day-old chicks was 0.9 µmol triethylamine/egg.

Information on the carcinogenicity of triethylamine in humans or animals is sparse. In a Danish foundry, molders exposed to a variety of chemicals including triethylamine had a significantly increased mortality due to death from bladder cancer. However, no tumors were detected in rats co-administered triethylamine and nitrite in feed for 1 year.

Limited data on the genetic toxicity of triethylamine were located. Triethylamine was not mutagenic in *Salmonella typhimurium*. *In vitro*, triethylamine did not induce sister chromatid exchanges (SCE) in Chinese hamster ovary cells, while *in vivo* it induced aneuploidy but was not clastogenic in the bone marrow of treated rats.

Pyrolysates of triethylamine were mutagenic in *S. typhimurium* strains TA98 and TA100 in the presence of metabolic activation. In an antigenotoxic study, triethylamine did not inhibit the induction of DNA damage by the radical initiator, 2,2'-azobis(2-amidinopropane) hydrochloride (AAPH).

Very few studies on the immunotoxic effects of triethylamine were found. Rats that received topical application of triethylamine and guinea pigs that were injected intracutaneously with triethylamine did not become sensitized.

A limited number of studies investigating other toxic effects of triethylamine were reviewed. *In vitro* and *in vivo* administration of triethylamine inhibited MAO activity in liver and brain of mice, and inhibited sulfotransferase activity toward dehydroepiandrosterone (DHEA), but not toward cortisol or 2-naphthol, in hepatic cytosolic preparations from rats. In rats, triethylamine did not inhibit the *N*-oxidation of azomethane to azoxymethane, an essential step in the metabolic activation of 1,2-dimethylhydrazine to a carcinogen. Triethylamine inhibited protein degradation and synthesis, and induced lysosomal swelling in isolated hepatocytes from rats. Triethylamine did not inhibit intercellular communication in Chinese hamster V79 cells.

No data were found on structure-activity relationships.

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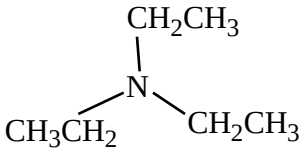
1.0 BASIS OF NOMINATION

The nomination of triethylamine [121-44-8] by Dr. Frank Mirer of the United Auto Workers is based on its high production volume, the large number of occupationally exposed workers, and the lack of carcinogenicity data.

2.0 CHEMICAL PROPERTIES

Triethylamine
[121-44-8]



2.1 Chemical Identification

Triethylamine ($C_6H_{15}N$, mol. wt = 101.19) is also called:

Ethanamine, *N*,*N*-diethyl- (9CI)
Amine, triethyl-
(Diethylamino) ethane
N,*N*-Diethylethanamine
TEA
TEN

Triethylamine has the designation for shipping UN1296.

2.2 Physical-Chemical Properties

Property	Information	Reference
Color	Colorless	Lewis (1992)
Physical State	Liquid	Budavari (1996)
Melting Point, °C	-115	Budavari (1996)
Boiling Point, °C	89.3	Weast and Astle (1980)

Property	Information	Reference
Specific Gravity at 25°C	0.7255	Lewis (1992)
Dissociation Constant (pKa)	10.76	Lewis (1992)
Odor	Strong ammoniacal odor	Budavari (1996)
Odor Threshold, ppm; v/v	0.48	Amoore & Hautala (1983)
Solubility:		
Water	Miscible in water	Lewis (1992)
Organic Solvents	Miscible in ethyl alcohol and ethyl ether	Lewis (1992)
Vapor Pressure Density	3.48	Lewis (1992)
Vapor pressure at 20°C, torr	54	ACGIH (1986)
Flash Point (^{o}C)	-11	BASF (1994; cited by BASF, 1995)
Auto Flammability (^{o}C)	215	BASF (1994; cited by BASF, 1995)

Triethylamine is a very dangerous fire hazard when exposed to heat, flame, or oxidizers. The vapor form is explosive when exposed to heat or flame. Triethylamine when complexed with dinitrogen tetraoxide and undiluted with solvent explodes at temperatures below 0°C. It will cause an exothermic reaction with maleic anhydride at temperatures above 150°C. Triethylamine can react with oxidizing materials and, when heated to decomposition, it emits toxic fumes of NO_x (Lewis, 1992).

2.3 Purity and Commercial Availability

Triethylamine is available in bulk quantities from Ashland Chemical Co., Industrial Chemicals & Solvents Division, BASF Corporation, Elf Atochem, North America, and Interchem Corporation (Strum, 1997). The product is sold by BASF Corporation in tank cars, tank trucks, 55-gal drums, and 5-gal pails.

3.0 PRODUCTION PROCESSES AND ANALYSES

Triethylamine is produced by reacting ammonia with ethanol, *N*,*N*-diethylacetamide with lithium aluminum hydride, or ethyl chloride with ammonia under heat and pressure (Nelson and Bull, 1990).

Large-scale manufacture of lower aliphatic amines is generally by high-temperature, high-pressure reaction of ammonia and an alcohol over a dehydration catalyst (method 1), or over a dehydrogenation catalyst (method 2) (Schweizer et al., 1978). Method 1 catalysts include alumina, silica-alumina, silica, titania, tungstic oxides, clays, or metal phosphates. Yields of mixed amines (primary, secondary, and tertiary) from the reaction of ammonia and alcohol in mole ratios of 2:1 to 6:1 are high (≥ 80%). The reaction product, comprising water, the alcohol, ammonia, and the amines, is treated by continuous extractions and distillations to produce the pure amines. Method 2 catalysts include silver, nickel, or copper. Byproducts include nitriles and amides. Separation of the desired product amines requires extractions and distillations. Less commonly, lower aliphatic amines are produced by treating an aldehyde or ketone with ammonia over a hydrogenation catalyst. Reaction conditions are similar to those of Method 2, but there is a net consumption of hydrogen.

4.0 PRODUCTION AND IMPORT VOLUMES

Triethylamine is produced by Air Products and Chemicals Inc., Elf Atochem North America Inc., and Hoechst Celanese Corporation (SRI Int., 1996). In 1995, 20 million pounds (9000 Mg) of triethylamine were consumed in the U.S.

5.0 USES

The largest use of triethylamine (totaling approximately 9 million pounds [4000 Mg] in 1995) was as a catalyst to cure the resin systems incorporated into sand cores for foundry molds (SRI Int., 1997). The cores are produced in what is typically called a cold box or isocure (Warren and Selchan, 1988). In this procedure, triethylamine is usually stored in liquid form at room temperature; during its use, it is vaporized into either a stream of air, nitrogen, or carbon dioxide and introduced into the system as a gas (MacBain and Strange, 1983; Warren and Selchan, 1988).

Workers must wear appropriate eye and respiratory protection (Conrard, 1977), and proper ventilation of the work area is necessary (Kay, 1974). In addition, annually in the U.S., approximately 5 million pounds (2000 Mg) of triethylamine was used as a curing catalyst in phenol-formaldehyde particleboard adhesives; 2-3 million pounds (900-1300 Mg) of triethylamine was used for the precipitation and purification of penicillin and cephalosporin antibiotics; and 1-2 million pounds (500-900 Mg) of triethylamine was used in the interfacial polymerization process for the production of polycarbonate resins. Consumption of triethylamine used as a scavenger of HCl produced during certain reactions, such as during the manufacture of benzyl phthalates from benzyl chloride and monophthalate esters, is limited because triethylamine is recovered and recycled. Triethylamine is also used as an ingredient in sealing paint (0.5% w/w) (Hansen et al., 1987); in the manufacture of some paper and board adhesives; reactions, as a stabilizer for the chlorinated solvents perchloroethylene and trichloroethylene (SRI Int., 1997); as an anti-livering agent for urea- and melamine-based enamels; in the recovery of gelled paint vehicles; as an accelerator activator for rubber; as a corrosion inhibitor; as a propellant; as a wetting, penetrating, and waterproofing agent of quaternary ammonium compounds; as an emulsifying agent for dyes; for the production of octadecyloxymethyltriethylammonium chloride (textile treatment agent); as an ingredient of photographic development accelerator; for drying of printing inks; in carpet cleaners; to solubilize 2,4,5-T in water; in the production of herbicides and pesticides and in the preparation of emulsifiers for pesticides; in nonnutritive sweeteners, ketenes, and salts; and for the desalination of water (Dangerous Prop. Ind. Mater. Rep., 1994).

6.0 ENVIRONMENTAL OCCURRENCE

6.1 Occurrence

Triethylamine enters into the environment mainly via emissions and effluents released during its production and use (HSDB, 1996). Triethylamine was detected at a concentration of 356.5 mg/L (3.52 mmol/L) in an effluent sample from the plastics and synthetics industry (HSDB, 1996). It has been found at concentrations of 0-4 μg/m^3 (0-0.04 μmol/m^3) in ambient air from an urban area (location not provided) (Kelly et al., 1994). Triethylamine was also detected in ambient air near a Russian plant that produced amines (500 m distance, 0.38 mg/m^3 [3.8 μmol/m^3]; 4000 m distance, 0.09 mg/m^3 [0.90 μmol/m^3]) (Tkachev, 1970). Triethylamine was not detected in air sampled from 757 randomly selected Canadian homes (Otson et al., 1994).

6.2 Persistence

If released on land, triethylamine will slowly volatilize and leach into soil, while in water, triethylamine is released slowly (half life, $t_{1/2}$ = 70 hr.) (HSDB, 1996). Adsorption to sediment is not appreciable (K_{oc} = 11-146), and bioconcentration in aquatic organisms is not expected. In air, triethylamine reacts with photochemically produced hydroxyl radicals and is scavenged by rain. In polluted air, triethylamine completely degrades photochemically in 90 minutes (HSDB, 1996). When irradiated, triethylamine is highly reactive, forming ozone, PAN, acetaldehyde, diethylnitroamine, diethylformamide, ethylacetamide, and diethylacetamide and aerosols (Pitts et al., 1978; cited by HSDB, 1996).

Triethylamine is not degraded by activated sludge, even when acclimatized (biological oxygen demand [BOD], 5.3% of theoretical after 13 days) (Chudoba et al., 1969; cited by HSDB, 1996), but triethylamine is completely degraded by *Aerobacter* in 11 hours (EPA, 1980; cited by HSDB, 1996).

7.0 HUMAN EXPOSURE

7.1 Occupational Exposure

Occupational exposure to triethylamine occurs mainly via inhalation and dermal contact with the vapor (HSDB, 1996). Cold box operators may be exposed to triethylamine if excess sand builds up in the apparatus, allowing the compound to escape from the seals around the cold box; if there are breaks in the hoses that supply triethylamine to the cold box; or if the core is removed from the cold box while it is still curing (Warren and Selchan, 1988; for review see also Reilly et al., 1995).

Workers applying paint containing triethylamine may also be exposed. For example, 4-6 mg/m^3 (40-60 $\mu mol/m^3$) of triethylamine was detected in the air where workers applied a waterborne sealing paint containing 0.5% triethylamine (w/w) to ceilings (Hansen et al., 1987).

Information on the number of U.S. workers potentially exposed to triethylamine is presented in **Table 1** by occupation, and in **Table 2** by industry. The inconsistencies in total numbers of plants and employees shown in Table 1 and Table 2 are due to the cited source.

Table 1. NIOSH National Occupational Exposure Survey (NOES)[a]: By Occupation

Occupation	Number of Plants	Number of Employees	Number of Female Employees
Agriculture and Biological Technicians, Except Health	33	660	n.p.
Assemblers	171	8185	2894
Carpenters	11	122	0
Chemical Engineers	74	301	0
Chemical Technicians	179	1591	n.p.
Chemists	178	1110	n.p.
Chemists, Except Biochemists	82	4711	1054
Clinical Laboratory Technologists and Technicians	20	420	317
Electrical and Electronic Technicians	6	22	0
Electricians	8	180	0
Engineering Technicians, N.E.C.	146	728	181

Occupation	Number of Plants	Number of Employees	Number of Female Employees
Extruding and Forming Machine Operators	44	265	0
Fabricating Machine Operators, N.E.C.	22	768	658
Foremen, N.E.C.	144	299	n.p.
Fork Lift and Tow Motor Operatives	11	53	n.p.
Freight and Material Handlers	69	558	n.p.
Furnace, Kiln, and Oven Operators, Except Food	6	18	0
Health Technologists and Technicians, N.E.C.	57	172	n.p.
Heavy Equipment Mechanics	19	3129	75
Industrial Machinery Repairers	94	1401	0
Industrial Truck and Tractor Equipment Operators	24	188	0
Insulation Workers	11	207	0
Janitors and Cleaners	170	2646	0
Laborers, Except Construction	270	1033	223
Machine Operatives, Miscellaneous Specified	204	1121	n.p.
Machine Operatives, Not Specified	61	775	n.p.
Machine Operators, Not Specified	277	2157	134
Machinery Maintenance Occupations	16	163	0
Machinists	38	4928	0
Managers and Administrators, N.E.C.	139	139	n.p.
Managers, Marketing, Advertising, and Public Relations	30	60	0
Medical Scientists	14	54	54
Millwrights	5	371	0
Miscellaneous Laborers	11	11	n.p.
Miscellaneous Machine Operators, N.E.C.	344	11451	968
Miscellaneous Material Moving Equipment Operators	7	600	104
Miscellaneous Mechanics and Repairmen	11	315	n.p.
Miscellaneous Metal and Plastic Processing Machine Operators	44	1578	306
Miscellaneous Operatives	52	300	n.p.
Miscellaneous Plant and System Operators	11	59	0
Miscellaneous Textile Machine Operators	92	1655	136
Mixing and Blending Machine Operators	304	2434	38

Occupation	Number of Plants	Number of Employees	Number of Female Employees
Mixing Operatives	243	1543	n.p.
Molders, Metal	11	116	n.p.
Molding and Casting Machine Operators	24	779	55
Molding and Casting Machine Operators[b]	5	622	55
Not Specified Laborers	21	74	n.p.
Not Specified Mechanics and Repairers	44	1844	199
Painters, Construction, and Maintenance	246	1637	400
Painters, Manufactured Articles	79	205	n.p.
Painting and Paint Spraying Machine Operators	1284	6073	485
Pattern and Model Makers, Except Paper	5	5	n.p.
Physicians, Medical and Osteopathic	174	349	n.p.
Plumbers, Pipefitters, and Steamfitters	9	189	0
Printing Machine Operators	21	41	41
Production Helpers	37	216	41
Production Inspectors, Checkers, and Examiners	11	113	85
Production Testers	33	100	33
Punch and Stamping Press Operatives	51	1131	n.p.
Science Technicians, N.E.C.	37	449	86
Sheet Metal Workers	24	188	24
Shoe Repairers	24	120	120
Slicing and Cutting Machine Operators	31	891	492
Solderers and Brazers	2	4	4
Supervisors, Mechanics, and Repairers	44	2429	0
Supervisors, Production Occupations	148	1003	130
Technicians, N.E.C.	33	33	0
Traffic, Shipping, and Receiving Clerks	130	199	0
Vehicle Washers and Equipment Cleaners	176	543	0
Water and Sewage Treatment Plant Operators	4	66	0
Welders and Cutters	13	208	0
Winding and Twisting Machine Operators	7	157	7
TOTAL	6564	79271	>9399

Abbreviations: N.E.C. = not elsewhere classified; n.p. = not provided

[a]NIOSH (1984)

[b] Triethylamine gas

Table 2. NIOSH National Occupational Exposure Survey (NOES)[a]: By Industry

Industry	Number of Plants	Number of Employees	Number of Female Employees
Apparel and Other Textile Products	68	2657	204
Auto Repair, Services, and Garages	235	469	0
Business Services	130	5692	898
Chemicals and Allied Products	262	14467	1694
Electric and Electronic Equipment	222	6297	2387
Electric, Gas, and Sanitary Services	21	629	0
Fabricated Metal Products	497	3299	340
Food and Kindred Products	26	157	0
Furniture and Fixtures	67	1046	0
Health Services	119	1169	622
Heavy Construction Contractors	19	3129	75
Instruments and Related Products	150	1931	897
Leather and Leather Products	92	196	227
Machinery, Except Electrical	684	12960	280
Medical and Other Health Services	232	521	n.p.
Misc. Manufacturing Industries	78	778	102
Paper and Allied Products	48	811	0
Petroleum and Coal Products	21	531	43
Primary Metal Industries	41	4649	0
Printing and Publishing	4	31	0
Rubber and Misc. Plastics Products	31	249	249
Special Trade Contractors	56	56	0
Stone, Clay, and Glass Products	31	2519	1628
Textile Mill Products	24	754	0
Tobacco Manufactures	3	16	0
Transportation Equipment	137	2227	57
Transportation Equipment[b]	5	622	55
Water Transportation	86	172	0
TOTAL	4116	78071	> 9758

[a]NIOSH (1984)
[b] Triethylamine gas

7.2 Non-occupational Exposure

In a Russian study, triethylamine was detected, but not quantitated, in boiled beef (Golovnya et al., 1979), indicating that a large number of people may be exposed to trace amounts from their diet. The general population may also be exposed to triethylamine from emissions released during its production and use (HSDB, 1996), see **Section 6.1**.

8.0 REGULATORY STATUS

The American Conference of Governmental Industrial Hygienists (ACGIH, 1986) has recommended an inhalation threshold limit value (TLV) for triethylamine of 10 ppm (40 mg/m^3) and a short-term exposure limit (STEL) of 15 ppm (60 mg/m^3). The concentration of triethylamine considered immediately dangerous to life or health (IDLH) is 1000 ppm (4000 mg/m^3) (NIOSH, 1990; cited by Dangerous Prop. Ind. Mater. Rep., 1994). The permissible exposure limit (PEL) for triethylamine regulated by the Occupational Safety and Health Administration (OSHA) under 29 CFR 1910 is 25 ppm (100 mg/m^3). OSHA's regulated threshold limit value (TLV) for triethylamine is 1 ppm (4 mg/m^3) and the 15-minute short-term-exposure limit (STEL) on skin is 3 ppm (12 mg/m^3) (NIOSH, 1997).

Triethylamine is classified under 49 CFR 172.101, for domestic transportation purposes, as a flammable liquid ; acceptable modes of transportation are air, rail, road, and water. Triethylamine is also regulated by the Department of Transportation (DOT) under the general requirements of 49 CFR 171.2, which states that "[n]o person may transport, offer, or accept a hazardous material for transportation in commerce unless that material is properly classed, described, packaged, marked, labeled, and in condition for shipment as required or authorized by the hazardous materials regulations."

Triethylamine is produced, as either an intermediate or a final product, by process units regulated by the Environmental Protection Agency (EPA) under 40 CFR 60.489. This action

promulgates standards of performance for equipment leaks of volatile organic compounds in the Synthetic Organic Chemical Manufacturing Industry (SOCMI). Under subpart F of 40 CFR 63, triethylamine is listed as a synthetic organic chemical in the chemical manufacturing industry and as an organic hazardous air pollutant subject to national emission standards. Under subpart G of 40 CFR 63, triethylamine is listed as an organic hazardous air pollutant subject to the wastewater provisions for process units at new and existing sources for the SOCMI. Under 40 CFR 116.4, triethylamine is designated as a hazardous substance in accordance with section 311(b)(2)(A) of the Federal Water Pollution Control Act and is further regulated by the Clean Water Act Amendments of 1977 and 1978. Pursuant to Section 311 of the Clean Water Act, the reportable quantity of triethylamine listed under 40 CFR 117.3 is 5000 lbs (2270 kg). Triethylamine is listed under 40 CFR 122.64 as a hazardous substance required to be identified by existing dischargers if expected to be present. Under 40 CFR 180.142 and 40 CFR 180.292, tolerances are established for residues (including the triethylamine salt) of the herbicide, plant regulator, and fungicide 2,4-D and of the pesticide picloram, respectively, in or on raw agricultural commodities. 40 CFR 261.33 lists triethylamine as a hazardous waste and the Resource Conservation and Recovery Act (RCRA) Appendix VIII lists the chemical as a hazardous constituent. The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) lists triethylamine as a hazardous substance under 40 CFR 302.4 and the reportable quantity is 5000 lbs (2270 kg). 40 CFR 371.65 sets forth requirements for the submission of information relating to the release of toxic chemicals, including triethylamine, under section 313 of Title III of the Superfund Amendments and Reauthorization Act (SARA) of 1986. 40 CFR 716.120 requires manufacturers, importers, and processors of triethylamine to submit copies and lists of unpublished health and safety studies to the EPA.

The Food and Drug Administration (FDA) lists triethylamine for use in testing and assaying the drug Loracarbef® under 21 CFR 443.20 and the drug Capreomycin Sulfate® under 21

CFR 448.15a. Triethylamine is listed under 21 CFR 436.366 for use in the high-performance liquid chromatography assay for determining the chromatographic purity of vancomycin. Under 21 CFR 175.105, polyurethane resins produced by reacting toluene diisocyanate or 4,4'-methylenebis(cyclohexylisocyanate) with triethylamine or by reacting tetramethylxylene diisocyanate with triethylamine are permitted for use in adhesives. The optional adjuvant substances required in the production of resins by the methods described in paragraph (a)(1) and (3) of 21 CFR 177.1580 may include triethylamine.

9.0 TOXICOLOGICAL DATA

Summary: Severe visual disturbances and changes in electrical activity in the cerebral cortex have been detected in human volunteers exposed to triethylamine by inhalation. Occupationally-exposed workers have reported visual disturbances associated with exposure to triethylamine. Several case reports also indicate that exposure to triethylamine causes ocular and respiratory abnormalities.

In humans, following exposure to triethylamine by inhalation, ingestion, or i.v. injection, triethylamine was excreted in urine largely unchanged, to a lesser extent as triethylamine-oxide (TEAO) and, in trace amounts, as diethylamine. The average plasma and urine half-lives for triethylamine was 3 to 4 hours.

The dermal LD_{50} for rabbits was 0.57-0.794 mL/kg (4.1-5.69 mmol/kg). The inhalation LD_{50} for mice and rats was 6000 mg/m^3 (1425 ppm; 59.29 mmol/m^3) and 420-10,000 mg/m^3 (99.8-2375 ppm; 4.16-98.82 mmol/m^3), respectively. The intraperitoneal (i.p.) LD_{50} was 183-405 mg/kg (1.81-4.00 mmol/kg) for mice, while the oral LD_{50} was 450-1000 mg/kg (4.45-9.88 mmol/kg) for mice and rats, 1460 mg/kg (14.4 mmol/kg) for rabbits, and 730 mg/kg (7.21 mmol/kg) for cats.

Acute animal studies revealed that triethylamine caused dermal and ocular irritation, and severe toxicity and death following inhalation or oral exposure. In short-term exposure studies, changes in lungs, brain, and liver were detected in albino rats exposed by inhalation to 13.01 mg/m^3 triethylamine for 3 months. No adverse effects were observed in rats exposed by inhalation to 25 or 247 ppm (100 or 1020 mg/m^3) for 28 weeks. Changes in the nervous system, hypohemoglobinemia, a rise in the number of reticulocytes in blood, and chronic inflammation of lungs were detected in rats exposed by inhalation to 30-80 mg/m^3 triethylamine for 6 months. In rats administered 5, 15, 30,

or 60 mg (0.05-0.59 mmol) triethylamine by gavage for 6 weeks, no adverse effects were observed with the 5- or 15-mg doses, and only slight toxicity was observed with the 30-mg dose. Treatment with 60 mg, however, caused convulsions, with females exhibiting the more severe reaction. Mortality was present among female but not male rats. Oral administration of multiple doses of 1 or 10 mg/kg (0.01 or 0.10 mmol/kg) triethylamine to rats caused changes in conditioned reflexes (duration of exposure not provided). No adverse effects were observed in rats orally administered 54.5 mg/kg (0.540 mmol/kg) triethylamine daily for 2 months.

In short-term studies with rabbits, severe ocular irritation was observed following exposure to 50 ppm (210 mg/m^3) triethylamine for 30 days, while lung and eye irritation was observed at 50 and 100 ppm (210 or 414 mg/m^3) for 6 weeks. Exposure to 100 ppm also caused degeneration and inflammation in liver and kidneys which led to deterioration of heart muscle. Administration of 6 mg/kg (0.06 mmol/kg) triethylamine to rabbits caused a transient effect on hepatic carbohydrate metabolism. Administration of a lower dose (1 mg/kg; 0.010 mmol/kg) had no adverse effect.

In a three-generation reproductive study in which rats were administered triethylamine in drinking water (first and second generation, 2 or 200 ppm [0.02 or 1.98 mM]; third generation, 500 ppm [4.94 mM]), the only adverse effect observed was a slightly reduced average body weight in third-generation rats. The development of ova into normal blastocysts was disrupted by oral administration of triethylamine to pregnant rabbits during gestation days 1-3 (dose not provided). The median effective dose (ED_{50}) for embryotoxicity in 3-day-old chicks was 0.9 µmol triethylamine/egg.

In a Danish foundry, molders exposed to a variety of chemicals including triethylamine had a significantly increased mortality due to death from bladder cancer. No tumors were detected in rats (strain and age not provided) co-administered 0.5% triethylamine (50 mmol/kg feed) and 0.5% nitrite in feed for 1 year.

Triethylamine, at concentrations up to 10,000 µg/plate (100 µmol/plate), was not mutagenic in *Salmonella typhimurium* in the presence or absence of metabolic activation. *In vitro*, triethylamine, at concentrations up to 17,900 µM, did not induce sister chromatid exchanges (SCE) in Chinese hamster ovary cells. I*n vivo*, triethylamine induced aneuploidy but was not clastogenic in the bone marrow of rats treated with 1 or 10 mg/m^3 (0.01 or 0.10 mmol/cm^3) triethylamine via continuous inhalation for 30 or 90 days. Pyrolysates of triethylamine, at concentrations up to 20 µmol/plate, were mutagenic in *S. typhimurium* strains TA98 and TA100 in the presence of metabolic activation. In an antigenotoxic study, triethylamine did not inhibit the induction of

DNA damage by the radical initiator, 2,2'-azobis(2-amidinopropane) hydrochloride (AAPH).

Rats that received topical application of triethylamine and guinea pigs that were injected intracutaneously with triethylamine did not become sensitized.

In vitro and *in vivo* administration of triethylamine inhibited MAO activity in liver and brain of mice, and inhibited sulfotransferase activity toward dehydroepiandrosterone (DHEA), but not toward cortisol or 2-naphthol, in hepatic cytosolic preparations from rats. In rats, triethylamine did not inhibit the *N*-oxidation of azomethane to azoxymethane, an essential step in the metabolic activation of 1,2-dimethylhydrazine to a carcinogen. Triethylamine inhibited protein degradation and synthesis, and induced lysosomal swelling in isolated hepatocytes from rats. Triethylamine did not inhibit intercellular communication in Chinese hamster V79 cells.

No data were found on structure-activity relationships.

9.1 General Toxicology

9.1.1 Human

9.1.1.1 Experimental

Changes in electrical activity in the cerebral cortex were detected in subjects exposed to 0.26 mg/m^3 (0.0026 mmol/m^3) triethylamine by inhalation (duration of exposure not provided) but not when exposed to 0.14 mg/m^3 (0.0014 mmol/m^3) (Tkachev, 1970).

Severe visual disturbances were reported in 2 healthy male volunteers exposed to 48 mg/m^3 (0.47 mmol/m^3) triethylamine vapor for 4 hours in an exposure chamber (Åkesson et al., 1985). Symptoms included heavy hazing of visual fields, inability to see outlines of objects 100 m or more away, bluish halos around lights, and slight eye irritation. Ocular examination revealed a slight decrease in visual acuity, pronounced epithelial corneal edema, slight conjunctival injection, and an increase in corneal thickness. Symptoms appeared 1 hour after the start of treatment and disappeared after 4 or 4.5 hr. Similar, but less severe, effects occurred after 2 hours of exposure to 34 mg/m^3 (0.34 mmol/m^3) triethylamine, while slight visual disturbance was

noted after 4-6 hours of exposure to 18 mg/m^3 (0.18 mmol/m^3) triethylamine. There were no adverse effects reported with exposure to 10 mg/m^3 (0.10 mmol/m^3) for 8 hours.

In another study, visual disturbances (blue haze) were reported in a healthy man exposed to 53 mg/m^3 (0.52 mmol/m^3) triethylamine vapor for 4 hours, in 2/2 men exposed to 35 mg/m^3 (0.35 mmol/m^3) triethylamine for 4 hours, and in 4/5 men exposed to 20 mg/m^3 (0.20 mmol/m^3) triethylamine for 8 hours (Åkesson et al, 1988). There were no adverse ocular effects reported with exposure to 10 mg/m^3 (0.10 mmol/m^3) for 8 hours.

9.1.1.2 Occupational

A researcher exposed to 50 ppm (210 mg/m^3; 2.0 mmol/m^3) triethylamine vapor during an animal toxicity study experienced severe corneal erosion and edema (Brieger and Hodes, 1951). The duration of exposure was not provided.

Three workers at Ashland Chemical Corporation involved in drumming triethylamine reported moderate to severe eye and upper respiratory tract irritation and halo vision with exposure to greater than 40 ppm (170 mg/m^3; 1.6 mmol/m^3) triethylamine (Ashland Chemical Co., 1986). The duration of exposure was not provided. Another worker who filled triethylamine cylinders reported that he experienced dry nose and throat and halo vision (concentration and duration of exposure not provided).

Workers employed at a polyurethane foam plant reported visual disturbances associated with triethylamine exposure (Åkesson et al., 1986). Symptoms included foggy vision, blue haze, and halo phenomenon that started after 1-3 hours of work and faded within 1 hour after work. Symptoms occurred in workers exposed to high time-weighted average (TWA) levels of triethylamine (12-13 mg/m^3; 0.12-0.13 mmol/m^3), but not in workers exposed to lower TWA levels (4-5 mg/m^3; 0.04-0.05 mmol/m^3). Exposure to the higher triethylamine levels were recorded at the trimming and mold opening/foam cell cracking stations; lower levels were recorded

at molding and other unspecified stations. In a similar study, Swedish workers employed in the plastics, spray molding, and pharmaceutical industries who were exposed to 40 mg/m^3 (0.40 mmol/m^3) triethylamine also experienced severe dimming of vision caused by corneal swelling and clouding (Arbetsmiljö, 1989). Symptoms persisted until the following day.

Workers at foundries using amine-cured cold box systems and who were exposed to greater than 5 ppm (20.5 mg/m^3; 0.20 mmol/m^3) triethylamine reported visual disturbances, whereas similar workers exposed to triethylamine levels less than or equal to 5 ppm were asymptomatic (Warren and Selchan, 1988). When an 8-hour TWA exposure was considered, the mean effective dose was 6.9 ppm (29 mg/m^3; 0.29 mmol/m^3); when short-term exposure was considered, the mean effective dose was 12.4 ppm (51.3 mg/m^3; 0.51 mmol/m^3).

In another study that included foundry workers using amine-cured cold box systems, there was also an increased incidence of vision abnormalities (i.e., blurriness, halos around lights, blue hazy vision) in cold box operators and their supervisors being exposed to 0.33 to 20.3 mg/m^3 (0.0033-0.20 mmol/m^3) triethylamine, as compared to workers previously or never exposed to triethylamine (Reilly et al., 1995). In currently exposed workers, the symptoms were more common among those exposed to greater than 10 mg/m^3 (greater than 0.10 mmol/m^3) triethylamine. The control group consisted of workers who were not cold box operators, but who were employed at the same Indiana foundry as the cold box operators.

9.1.2 Chemical Disposition, Metabolism, and Toxicokinetics

In humans, following exposure by inhalation, ingestion, or intravenous (i.v.) injection, triethylamine is excreted in urine unchanged, as triethylamine-*N*-oxide (TEAO), and in trace amounts as diethylamine (Åkesson et al., 1988; 1989a,b). Intake of ethanol by humans exposed to triethylamine by inhalation inhibits the renal clearance of triethylamine into TEAO and decreases plasma levels of triethylamine and TEAO (Åkesson and Skerfving, 1990).

In 5 healthy men exposed to 10, 20, 25, or 35 mg/m^3 (0.10, 0.20, 0.25, or 0.35 mmol/m^3) triethylamine by inhalation for 4 or 8 hours, an average of 97% of the calculated inhaled amount of triethylamine was excreted in urine as triethylamine and TEAO during the exposure period and for up to 32 hours after. TEAO accounted for an average of 24% of the excreted dose (Åkesson et al., 1988). The average urinary excretion half-life for triethylamine after exposure to 10 or 20 mg/m^3 (0.10 or 0.20 mmol/m^3) was approximately 3 hours.

In 20 workers (12 men, 8 women) employed at a polyurethane foam manufacturing plant, and who inhaled an average of approximately 500 µmol triethylamine per day, approximately 53% of the dose was excreted in urine as unchanged triethylamine and approximately 27% was excreted as TEAO during a 24-hour period (Åkesson et al., 1989a). Less than 0.3% was excreted as diethylamine. The average half-lives for triethylamine and TEAO in urine were 2.8 and 3.7 hours, respectively. The workers evaluated in this study were also occupationally exposed to other compounds, including dimethylethanolamine, triethylenediamine, triethanolamine, toluenediisocyanate, methylenediphenyldiisocyanate, trichlorofluoromethane, 1,1,1-trichloroethane, waxes, and a neoprene glue.

Approximately 1 day after oral (p.o.) or intravenous (i.v.) administration of a single dose of triethylamine to healthy male volunteers, an average of 94% (p.o.) or 97% (i.v.) of the dose was excreted in urine as unchanged triethylamine and TEAO (Åkesson et al., 1989b). Unchanged triethylamine accounted for approximately 2/3 of the administered dose and TEAO accounted for approximately 1/3 of the administered dose. Only a trace amount (< 0.5% of the dose) was excreted in urine as diethylamine. With p.o. administration, the average plasma and urine half-lives were 2.9 and 2.8 hours, respectively. With i.v. administration, the average plasma and urine half-lives were 3.7 and 3.6 hours, respectively.

9.1.3 Acute Exposure

The LD_{50}, LD_{Lo}, and RD_{50} data for triethylamine are presented in **Tables 3a, 3b, and 3c**, respectively; other acute exposure data are summarized in **Table 4**.

Table 3a. LD_{50} Values for Triethylamine

Route	Species (Sex and Strain)	LD_{50}	Reference
dermal	rabbit (male albino)	0.57 mL/kg (4.1 mmol/kg)	Union Carbide (1949); Smyth et al. (1951)
	rabbit (male albino)	0.794 mL/kg (5.69 mmol/kg)	Union Carbide (1979)
inhalation	mouse (sex and strain n.p.)	6000 mg/m^3 (1425 ppm; 59.29 mmol/m^3)	Toxicol. New Indust. Chem. Subst. (1965; cited by RTECS, 1996)
	rat (sex and strain n.p.)	420-590 mg/m^3 (99.8-140 ppm; 4.16-5.83 mmol/m^3)	Ashland Chemical Co. (1970; cited by BASF, 1995)
	rat (male albino)	> 2 mg/L (2000 mg/m^3; 500 ppm; 20 mmol/m^3)	Air Products & Chemicals (1976b)
	rat (sex and strain n.p.)	10,000 mg/m^3 (2375 ppm; 98.82 mmol/m^3)	Union Carbide (1979)
	mammal (sex, strain, and species n.p.)	6000 mg/m^3 (1425 ppm; 59.29 mmol/m^3)	Toxicol. New Indust. Chem. Subst. (1975; cited by RTECS, 1996)
i.p.	mouse (sex and strain n.p.)	183 mg/kg (1.81 mmol/kg)	BASF (1960; cited by BASF, 1995)
	mouse (sex and strain n.p.)	405 mg/kg (4.00 mmol/kg)	J. Pharm. (1977; cited by RTECS, 1996)
oral	mouse (sex and strain n.p.)	546 mg/kg (5.40 mmol/kg)	Hyg. Sanit. (1965; cited by RTECS, 1996)
	mouse (sex n.p., albino)	545.8 mg/kg (5.39 mmol/kg)	Kagan (1965)
	rat (male albino)	460 mg/kg (4.55 mmol/kg)	Union Carbide (1949); Smyth et al. (1951)
	rat (sex and strain n.p.)	460 mg/kg (4.55 mmol/kg)	AMA Arch. Indust. Hyg. Occup. Med. (1951; cited by RTECS, 1996)
	rat (sex and strain n.p.)	730 mg/kg (7.21 mmol/kg)	BASF (1960; cited by BASF, 1995)
	rat (male Wistar)	1.41 mL/kg (10.1 mmol/kg)	Union Carbide (1979)
	rabbit (sex and strain n.p.)	1460 mg/kg (14.4 mmol/kg)	BASF (1960; cited by BASF, 1995)

	cat (sex and strain n.p.)	730 mg/kg (7.21 mmol/kg)	BASF (1960; cited by BASF, 1995)

Abbreviations: i.p. = intraperitoneal; n.p. = not provided

Table 3b. LD_{Lo} Values for Triethylamine

Route	Species (Sex and Strain)	LD_{Lo}	Reference
inhalation	human (sex n.p.)	12 mg/m^3 (2.9 ppm; 0.12 mmol/m^3)	Int. Arch. Occup. Env. Health (1986; cited by RTECS, 1996)
	rat (sex and strain n.p.)	4200 mg/m^3 (997.6 ppm; 41.51 mmol/m^3)	Smyth et al. (1951; cited by BASF, 1995)
	rat (sex and strain n.p.)	4000 mg/m^3 (950.1 ppm; 39.53 mmol/m^3)	AMA Arch. Indust. Hyg. Occup. Med. (1951; cited by RTECS, 1996)
	guinea pig (sex and strain n.p.)	4000 mg/m^3 (950.1 ppm; 39.53 mmol/m^3)	J. Indust. Hyg. Toxicol. (1948; cited by RTECS, 1996)
i.p.	rat (sex and strain n.p.)	75 mg/kg (0.74 mmol/kg)	Farmakologiya i Toksikologiya (1968; cited by RTECS, 1996)
oral	rabbit (pregnant; strain n.p.)	6.9 mg/kg (0.068 mmol/kg)	FESTAS (1964; cited by Dangerous Prop. Ind. Mater. Rep., 1994)

Abbreviations: i.p. = intraperitoneal; LDLo = lowest lethal dose; n.p. = not provided

Table 3c. RD_{50} Values for Triethylamine

Route	Species (Sex and Strain)	RD_{50}	Reference
inhalation	mouse (male Swiss OF_1)	156 mg/m^3 (37.1 ppm; 1.54 mmol/m^3)	Gagnaire et al. (1989)
	mouse (male CF-1)	770 mg/m^3 (183 ppm; 7.61 mmol/m^3)	Nielsen and Yamagiwa (1989)
	mouse (male CF-1; cannulated)	2900 mg/m^3 (688.8 ppm; 28.66 mmol/m^3)	Nielsen and Yamagiwa (1989)

Abbreviations: n.p. = not provided; RD_{50} = the dose responsible for a decrease of 50% in the respiratory frequency

Table 4. Acute Toxicity of Triethylamine

Species, Strain, Age	Number and Sex of Animals	Chemical Form, Purity	Dose	Exposure/Observation Period	Results/Comments	Reference
9.1.3.1 Dermal Exposure						
guinea pig (strain and age n.p.)	n.p.	triethylamine, purity n.p.	70% solution	up to 2 hr; observation period n.p.	When the solution was dropped on skin, it quickly caused skin burns leading to necrosis. When the solution was held in place for 2 hr, there was severe skin irritation, necrosis, and scarring.	Proctor and Hughes (1978; cited by Beard and Noe, 1981)
rabbit (New Zealand white, 11- to 12-wk-old)	exposed: 1 M controls: 0	triethylamine, 99.5% pure	0.5 mL (400 mg; 4 mmol) applied to 3 occluded intact sites on dorsum	3 min; rabbit was sacrificed 3 min after dosing because of corrosivity	Corrosive effects were observed.	Union Carbide (1986)
rabbit (New Zealand white, young adult)	exposed: 6 (sex n.p.) controls: 0	triethylamine, purity n.p.	0.5 mL (400 mg; 4 mmol) applied to occluded intact skin of left and right flanks	3 min (right flank) or 1 hr (left flank); 7 day observation period	Corrosive effects were observed on the left and right flanks.	Hoechst Celanese Corp.(1989)
rabbit (New Zealand white; age n.p.)	exposed: 3 (sex n.p.) controls: 0	triethylamine, purity n.p.	0.5 mL (400 mg/ 4 mmol) applied to occluded intact and abraded skin	24 hr; 7 day observation period	Corrosive effects were observed.	Pennwalt Corporation (1986)
rabbit (strain and age n.p.)	exposed: 4 per dose (sex n.p.) controls: 0	triethylamine, purity n.p.	200, 2000, or 5000 mg/kg (1.98, 19.76, or 49.41 mmol/kg)	n.p.	0/4 low-, 3/4 mid-, and 4/4 high-dose rabbits died. In low- and mid-dose rabbits, severe dermal responses were observed from day 1 or 2 through day 7 (high-dose animals not evaluated). It was not specified if skin was occluded.	Virginia Chemicals (1987a)
rabbit (New Zealand white; age n.p.)	M (number n.p.)	triethylamine, purity n.p.	2.0 mL/kg (1400 mg/kg; 14 mmol/kg) applied to occluded trunk skin	24 hr; observation period n.p.	Death occurred within 4 hr Other signs of toxicity included severe skin damage, pale and mottled liver and kidneys, and hemorrhage or congestion of other, unspecified, organs.	Union Carbide (1949)

Abbreviations: M = male; n.p. = not provided

Table 4. Acute Toxicity of Triethylamine (continued)

Species, Strain, Age	Number and Sex of Animals	Chemical Form, Purity	Dose	Exposure/Observation Period	Results/Comments	Reference
rabbit (albino, 3- to 5-mo-old)	exposed: 4 each for low and mid dose; 2 for high dose (sex n.p.) controls: 0	triethylamine, purity n.p.	0.5, 1.0, or 2.0 mL/kg (400, 720, or 1400 mg/kg; 4, 7.2, or 14 mmol/kg) applied to occluded skin	n.p.	All high-dose and 3/4 mid-dose rabbits died within 1 day. None of the low-dose rabbits died. In dead rabbits, dark lungs and kidneys, pale liver and spleen, and mottled liver were observed.	Union Carbide (1979)
rabbit (strain and age n.p.)	exposed: 5 (sex n.p.) controls: 0	triethylamine, purity n.p.	0.01 mL (7 mg; 0.07 mmol) applied to belly	n.p.	Triethylamine was a grade 2 irritant (on a scale of 0-10). It was not specified if skin was occluded.	Union Carbide (1949)
rabbit (New Zealand white; age n.p.)	exposed: 6 (sex n.p.) controls: 0	triethylamine, purity n.p.	0.5 mL (400 mg; 4 mmol) applied to occluded intact and abraded skin	4 hr; 72 hr observation period	Slight to moderate irritation was observed in intact and abraded skin.	Air Products & Chemicals, Inc. (1976a)
rabbit (strain and age n.p.)	n.p.	triethylamine, purity n.p.	10 mg (0.10 mmol) applied to abraded skin; uncovered	24 hr; observation period n.p.	Mild irritation was observed.	AMA Arch. Indust. Hyg. Occup. Med. (1951; cited by RTECS, 1996)
rabbit (strain and age n.p.)	n.p.	triethylamine, purity n.p.	365 mg (3.61 mmol) applied to abraded skin; uncovered	n.p.	Mild irritation was observed.	Union Carbide (1970; cited by RTECS, 1996)
rabbit (strain and age n.p.)	n.p.	triethylamine, purity n.p.	500 mg (4.94 mmol)	24 hr; observation period n.p.	Mild irritation was observed. It was not specified if skin was occluded.	Marhold (1986; cited by RTECS, 1996)
9.1.3.2 Inhalation Exposure						

Abbreviations: M = male; n.p. = not provided

Table 4. Acute Toxicity of Triethylamine (continued)

Species, Strain, Age	Number and Sex of Animals	Chemical Form, Purity	Dose	Exposure/Observation Period	Results/Comments	Reference
rat (strain and age n.p.)	exposed: 4 M per dose controls: 0	triethylamine, purity n.p.	80, 100, 120, or 140 ppm (330-579 mg/m^3; 3.3-5.7 mmol/m^3)	1 hr; 10 day observation period	All rats exposed to 140 ppm died within 20 min after start of treatment. After 10 days, 3/4 rats exposed to 80 ppm, 2/4 rats exposed to 100 ppm, and 2/4 rats exposed to 120 ppm had died. Dyspnea, tremors, ocular erythema and discharge, nasal discharge, salivation, and collapse were observed during treatment. Necropsy revealed congestion of lungs and gastrointestinal inflammation.	Ashland Chemical Company (1970)
rat (strain and age n.p.)	exposed: 6 (sex n.p.) controls: n.p.	triethylamine, purity n.p.	1000 ppm (4140 mg/m^3; 40.9 mmol/m^3)	4 hr; 14 day observation period	One of six rats died.	Smyth et al. (1951)
rat (strain and age n.p.)	exposed: 6 per dose (sex n.p.) controls: 0	triethylamine, purity n.p.	500, 1000, or 2000 ppm (2070, 4140, or 8280 mg/m^3; 20.4, 40.9, or 81.8 mmol/m^3)	4 hr; observation period n.p.	All high-dose rats died within 2 to 4 hours after start of exposure. The lungs, livers, and kidneys of high-dose rats were found to be congested at necropsy. The mid and low doses caused death in 1/6 and 0/6 rats, respectively.	Union Carbide (1949)
rat (strain and age n.p.)	exposed: 6 per dose (sex n.p.) controls: 0	triethylamine, purity n.p.	2000 or 4000 ppm (8280 or 16,560 mg/m^3; 81.8 or 164 mmol/m^3)	4 hr; observation period n.p.	All high-dose and 1/6 low-dose rats died during exposure. Signs of toxicity included irritated extremities and loss of coordination.	Union Carbide (1979)
rat (albino; age n.p.)	exposed: 10 M controls: 0	triethylamine, purity n.p.	0.5 ppm (2 mg/m^3; 0.02 mmol/m^3)	1 hr; 14 day observation period	Huddling was observed during treatment.	Air Products & Chemicals, Inc. (1976b)
guinea pig (strain and age n.p.)	exposed: 6 per dose (sex n.p.) controls: 0	triethylamine, purity n.p.	250, 500, 1000, or 2000 ppm (1030- 8280 mg/m^3; 10.2-81.8 mmol/m^3)	30 min (250 and 2000 ppm), 2 hr (2000 ppm), or 4 hr (250, 500, and 1000 ppm); observation period n.p.	Death occurred in 2/6 guinea pigs exposed to 1000 ppm for 4 hr and in 4/6 guinea pigs exposed to 2000 ppm for 2 hr There were no other deaths.	Carpenter et al. (1948)
9.1.3.3 Ocular Exposure						

Abbreviations: M = male; n.p. = not provided

Table 4. Acute Toxicity of Triethylamine (continued)

Species, Strain, Age	Number and Sex of Animals	Chemical Form, Purity	Dose	Exposure/Observation Period	Results/Comments	Reference
rabbit (strain and age n.p.)	n.p.	triethylamine, purity n.p.	1 or 5% dilution in propylene glycol (100 or 500 mM) (volume n.p.)	n.p.	The high dose caused severe ocular injury. The low dose did not cause any irritation. Triethylamine was categorized as a grade 9 ocular irritant (on a scale of 0-10).	Union Carbide (1949)
rabbit (strain and age n.p.)	n.p.	triethylamine, purity n.p.	from 0.005 mL per eye of undiluted compound and from 0.5 mL per eye of a 1 or 5% dilution in water (100 or 500 mM)	n.p.	Severe corneal injury was observed with undiluted compound and 5% solution. Moderate corneal injury occurred with 1% solution.	Union Carbide (1979)
rabbit (New Zealand white; age n.p.)	exposed: 3 (sex n.p.) controls: 0	triethylamine, purity n.p.	0.1 mL (70 mg; 0.7 mmol) instilled in conjunctival sac of eyes; 1 eye was washed after 15 sec.	15 sec. or 7 days; 7 day observation period	Severe irritation was observed in unwashed eyes; moderate irritation was observed in washed eyes.	Pennwalt Corporation (1986)
rabbit (strain and age n.p.)	n.p.	triethylamine, purity n.p.	0.25 mg (0.0025 mmol)	24 hr; observation period n.p.	Severe irritation was observed.	Marhold (1986; cited by RTECS, 1996)
rabbit (strain and age n.p.)	n.p.	triethylamine, purity n.p.	250 mg (2.5 mmol)	n.p.	Severe irritation was observed.	AMA Arch. Indust. Hyg. Occup. Med. (1951; cited by RTECS, 1996)
cat (mongrel; age n.p.)	exposed: 3 cats (sex n.p.) controls: n.p.	triethylamine, purity n.p.	0.450 or 0.850 mmol vapor/5 min; vapor was directed at the cornea	single or double dose applied for 1-5 min; observation period n.p.	Severe corneal damage was observed in all cats.	Potts et al. (1986)

Abbreviations: M = male; n.p. = not provided

Table 4. Acute Toxicity of Triethylamine (continued)

Species, Strain, Age	Number and Sex of Animals	Chemical Form, Purity	Dose	Exposure/Observation Period	Results/Comments	Reference
monkey (cynomolgus; age n.p.)	exposed: 1 monkey (sex n.p.) controls: n.p.	triethylamine, purity n.p.	0.450 or 0.850 mmol vapor/5 min; vapor was directed at the cornea	single or double dose applied for 1-5 min; observation period n.p.	Severe corneal damage was observed.	
9.1.3.4 Oral Exposure						
rat (albino; age n.p.)	n.p.	triethylamine, purity n.p.	20% solution in 1% Tergitol 7, administered by gavage	single dose; observation period n.p.	Signs of toxicity included hemorrhage of the stomach and intestines, and congestion of liver and kidneys.	Union Carbide (1949)
rat (3- to 4-wk-old Wistar)	exposed: 5M per dose controls: 0	triethylamine, purity n.p.	0.25, 0.5, or 1.0 mL/kg (180, 360, or 720 mg/kg; 1.8, 3.6, or 7.2 mmol/kg) undiluted compound, or 0.5, 1.0, or 2.0 mL/kg (360, 720, or 1400 mg/kg; 3.6, 7.2, or 14 mmol/kg) diluted compound (1 mL = 0.1 mL in distilled water), administered by gavage	single dose; observation period n.p.	All rats given 1.0 mL/kg undiluted compound or 2.0 mL/kg diluted compound died within 1 day after treatment. 4/5 and 3/5 rats given 0.5 and 0.25 mL/kg, respectively, undiluted compound died within approximately 1 week. Rats in other groups did not die. Toxic symptoms were seen in lungs, stomach, pylori, intestines, kidneys, adrenals, and liver.	Union Carbide (1979)

Abbreviations: M = male; n.p. = not provided

9.1.3.1 Dermal Exposure

Severe skin damage was observed in guinea pigs (strain not provided) that had a 70% solution (solvent not provided) of triethylamine either dropped on the skin or held to the skin for 2 hours (Proctor and Hughes, 1978; cited by Beard and Noe, 1981).

Severe skin damage was also observed in New Zealand white rabbits that had 0.5 mL triethylamine applied to intact or abraded occluded skin either for 3 minutes (Union Carbide, 1986; Hoechst Celanese Corp., 1989) or for 24 hours (Pennwalt Corp., 1986), and in rabbits (strain not provided) that received 200, 2000, or 5000 mg/kg triethylamine (1.98, 19.76, or 49.41 mmol/kg) (Virginia Chemicals, 1987a). In the latter study, 75% and 100% mortality was induced by 2000 and 5000 mg/kg (19.76 and 49.41 mmol/kg), respectively.

Severe toxicity leading to death was observed in New Zealand white rabbits that had 1.0 or 2.0 mL/kg triethylamine applied to skin for 24 hours (Union Carbide, 1949; 1979). In dead rabbits, dark lungs and kidneys, pale liver and spleen, and mottled liver were observed.

Mild to moderate skin irritation was observed in rabbits that had 0.01 mL triethylamine applied to skin (duration of exposure not provided) (Union Carbide, 1949), in New Zealand white rabbits that had 0.5 mL triethylamine applied to intact or abraded skin for 4 hours (Air Products & Chemicals Inc., 1976a) and in rabbits (strain not provided) that had 10-500 mg (0.10-4.94 mmol) triethylamine applied to skin for 24 hours (AMA Arch. Indust. Hyg. Occup. Med., 1951, Union Carbide, 1970, and Marhold, 1986; all cited by RTECS, 1996).

9.1.3.2 Inhalation Exposure

Severe toxicity leading to death was observed among rats (strain not provided) exposed for 1 hour to triethylamine at 80-140 ppm (330-579 mg/m^3; 3.3-5.73 mmol/m^3) (Ashland Chemical Company, 1970) or for 4 hours to 1000, 2000, or 4000 ppm (4140, 8280, or 16,560 mg/m^3; 40.9, 81.8, or 164 mmol/m^3) (Smyth et al., 1951; Union Carbide, 1949, 1979). At 80-140

ppm (330-579 mg/m^3; 3.3-5.7 mmol/m^3), dyspnea, tremors, ocular erythema and discharge, nasal discharge, salivation, and collapse were observed during treatment, while necropsy revealed congestion of lungs and gastrointestinal inflammation (Ashland Chemical Company, 1970). Among the rats that died at 2000 ppm (8280 mg/m^3; 81.8 mmol/m^3), the lungs, livers, and kidneys were found to be congested at necropsy (Union Carbide, 1949). Rats exposed to 4000 ppm (16,560 mg/m^3; 164 mmol/m^3) were not necropsied (Union Carbide, 1979). Exposure of albino rats to 0.5 ppm (2 mg/m^3; 0.02 mmol/m^3) for 1 hour was not toxic; only huddling during treatment was observed (Air Products & Chemicals Inc., 1976b).

Severe toxicity leading to death was observed also in some guinea pigs exposed to 1000 or 2000 ppm (4140 or 8280 mg/m^3; 4.09 or 81.8 mmol/m^3) triethylamine for 30 minutes (Carpenter et al., 1948).

9.1.3.3 Ocular Exposure

Severe ocular injury was observed in rabbits (strain not provided) that had 0.005 mL undiluted triethylamine, 0.5 mL of a 5% (500 mM) triethylamine aqueous solution, or a 5% solution in propylene glycol (500 mM) placed in eyes for an unspecified time (Union Carbide, 1949, 1979); in New Zealand white rabbits that had 0.1 mL undiluted triethylamine instilled in conjunctival sacs and left unwashed for 7 days (Pennwalt Corporation, 1986); and in rabbits (strain not provided) that had 0.25 or 250 mg (0.0025 or 2.50 mmol) undiluted triethylamine placed in eyes for either 24 hours (0.25 mg) or for an unspecified period of time (250 mg) (Marhold, 1986, and AMA Arch. Indust. Hyg. Occup. Med., 1951; both cited by RTECS, 1996).

Moderate ocular damage occurred in rabbits with a 15-second exposure to 0.1 mL of undiluted triethylamine (Pennwalt Corporation, 1986) or with administration of a 1% aqueous solution (100 mM) of triethylamine (duration of exposure not provided) (Union Carbide, 1979).

In an earlier study, however, administration of a 1% solution in propylene glycol (100 mM) caused no irritation to rabbit eyes (Union Carbide, 1949).

Severe ocular damage was observed in cats and monkeys exposed to 0.450 or 0.850 mmol triethylamine vapor directed at the cornea for 5 minutes (Potts et al., 1986).

9.1.3.4 Oral Exposure

Severe toxicity leading to death was observed among albino rats administered by gavage a single dose of a 20% dispersion of triethylamine in 1% Tergitol 7 (Union Carbide, 1949), and among Wistar rats administered by gavage either a single dose of 0.25-1.0 mL/kg undiluted triethylamine, or 2.0 mL/kg diluted triethylamine (1 mL = 0.1 mL in water) (Union Carbide, 1979). Signs of toxicity in albino rats included hemorrhage of the stomach and intestines, and congestion of liver and kidneys. All Wistar rats given 1.0 mL/kg undiluted compound or 2.0 mL/kg diluted compound died within 1 day after treatment. Four of 5 and 3/5 Wistar rats given 0.5 and 0.25 mL/kg, respectively, undiluted compound died within approximately 1 week. Toxic effects were seen in lungs, stomach, pylori, intestines, kidneys, adrenals, and liver.

9.1.4 Short-Term and Subchronic Toxicity of Triethylamine

The studies described in this section are summarized in **Table 5**.

9.1.4.1 Inhalation Exposure

Changes in lungs, brain, and liver were detected in albino rats exposed to 13.01 mg/m^3 (3.14 ppm; 0.130 mmol/m^3) triethylamine for 3 months (Tkachev, 1970). In lungs, there was infiltration of the perivascular connective tissue by white blood cells, thickening of the interalveolar walls, and shedding of the alveolar epithelium. In the brain, there was swelling, disruption of nuclei, necrosis, disappearance of neurons, reduced cytochrome oxidase activity,

accumulation of lipids in the cerebral cortex, and reduced staining intensity of sulfhydryl groups. In the liver, there was a reduction in glycogen content. Exposure to lower doses (0.16 or 1.71 mg/m^3; 0.039 or 0.41 ppm; 0.0016 or 0.017 $mmol/m^3$) did not produce these changes.

Moderate necrotizing inflammation of the nasal cavity occurred in all male and female Fischer 344 rats exposed to 1000 ppm (4138 mg/m^3; 41 $mmol/m^3$) triethylamine for 10 days (Schueler, 1984). Additionally, some rats had slight to moderate perivascular edema of the lungs, slight to moderate squamous metaplasia of the trachea, and moderate thymic atrophy.

No adverse effects were observed in Fischer-344 rats exposed to 25 or 247 ppm (100 or 1020 mg/m^3; 1 or 10 $mmol/m^3$), 6 hr/day, 5 days/wk for 28 weeks (Lynch et al., 1990).

Lung and eye irritation but no mortality was observed in rabbits (strain not provided) exposed to 50 or 100 ppm (210 or 414 mg/m^3; 2.0 or 4.1 $mmol/m^3$) triethylamine, 7 hr/day, 5 days/wk for 6 weeks (Brieger and Hodes, 1951). Exposure to 100 ppm (414 mg/m^3; 4.1 $mmol/m^3$) also caused parenchymatous degeneration and occasionally inflammatory processes in liver and kidneys. Triethylamine exposure also led to degeneration of heart muscle.

9.1.4.2 Ocular Exposure

Severe ocular irritation was observed in rabbits (strain not provided) exposed to 50 ppm triethylamine (solvent not provided) for 30 days (AMA Arch. Indust. Hyg. Occup. Med., 1951; cited by RTECS, 1996).

Table 5. Short-Term and Subchronic Toxicity of Triethylamine

Species, Strain, Age	Number and Sex of Animals	Chemical Form, Purity	Dose	Exposure/ Observation Period	Results/Comments	Reference
9.1.4.1 Inhalation Exposure						
rat (albino; age n.p.)	exposed: 20 rats per dose (sex n.p.) controls: 20 rats (sex n.p.)	triethylamine, purity n.p.	0.16, 1.71, or 13.01 mg/m^3 (0.039, 0.41, or 3.14 ppm; 0.0016, 0.017, or 0.13 mmol/m^3)	3 mo; observation period n.p.	Seventy-five days after the start of treatment, all rats were starved for 3 days. The high dose caused changes in lungs, brain, and liver. In lungs, there was infiltration of the perivascular connective tissue by white blood cells, thickening of the interalveolar walls, and shedding of the alveolar epithelium. In the brain, there was swelling, disruption of nuclei, necrosis, disappearance of neurons, reduced cytochrome oxidase activity, accumulation of lipids in the cerebral cortex, and reduced staining intensity of sulfhydryl groups. In the liver, there was a reduction in glycogen content.	Tkachev (1970)
rat (Fischer 344, age n.p.)	exposed: 4 M, 4 F (low dose); 5 M, 5 F (high dose) controls: 10 M, 10 F	triethylamine, purity n.p.	250 or 1000 ppm (1030 or 4139 mg/m^3; 10 or 41 mmol/m^3)	10-day exposure over 2-week period (no exposure on weekends); observation period n.p.	The high dose induced moderate necrotizing inflammation of the nasal cavity in all dosed rats. Slight to moderate perivascular edema was present in the lungs of 2/5 males and 1/5 females exposed to the high dose. Also at the high dose, slight to moderate squamous metaplasia of the trachea was noted in 3/5 males and 4/5 females and moderate thymic atrophy was observed in 3/5 males and 4/5 females.	Schueler (1984)
rat (Fischer-344; age n.p.)	exposed: 50 M, 50 F per dose controls: 50 M, 50 F	triethylamine, > 99.9% pure	25 or 247 ppm (100 or 1020 mg/m^3; 1 or 10 mmol/m^3), 6 hr/day, 5 days/wk	28 wk; rats were killed either during treatment or after 28 wk of treatment	Body and organ weights were not affected by exposure. There was no evidence of cardiotoxicity and there were no gross or histopathologic lesions observed in lungs, liver, kidneys, heart, spleen, tracheobronchial lymph nodes, adrenals, urinary bladder, testes, seminal vesicles, uterus, ovaries, trachea, eyes, or nasal passages.	Lynch et al. (1990)
rabbit (strain and age n.p.)	n.p.	triethylamine, purity n.p.	50 or 100 ppm (210 or 414 mg/m^3; 2.0 or 4.1 mmol/m^3), 7 hr/day, 5 days/wk	6 wk; observation period n.p.	There were no deaths. Lung and eye irritation was observed in rabbits exposed to 50 or 100 ppm. Exposure to 100 ppm caused parenchymatous degeneration and inflammation in liver and kidneys. Degeneration of heart muscle was also observed.	Brieger and Hodes (1951)
9.1.4.2 Ocular Exposure						

Abbreviations: F = female; M = male; n.p. = not provided

Table 5. Short-Term and Subchronic Toxicity of Triethylamine (continued)

Species, Strain, Age	Number and Sex of Animals	Chemical Form, Purity	Dose	Exposure/ Observation Period	Results/Comments	Reference
rabbit (strain and age n.p.)	n.p.	triethylamine, purity n.p.	50 ppm (solvent and dosing schedule n.p.)	30 days; no observation period	Severe ocular irritation was observed.	AMA Arch. Indust. Hyg. Occup. Med. (1951; cited by RTECS, 1996)
9.1.4.3 Oral Exposure						
rat (strain n.p.; 3-mo-old)	exposed: 5 M, 5 F per dose controls: 5 M, 5 F	triethylamine, purity n.p.	5, 15, 30, or 60 mg (0.05, 0.15, 0.30, or 0.59 mmol) by gavage, 3 times/wk (vehicle n.p.)	6 wk; no observation period	No adverse effects were observed in rats treated with 5 or 15 mg and only slight toxicity was observed with the 30-mg dose. Treatment with 60 mg caused convulsions, females had a more severe reaction than males. 3/5 females treated with 60 mg died before the end of the study; all high-dose males survived.	EPA (1965)
rat (albino; age n.p.)	n.p.	triethylamine, purity n.p.	0.1, 1, or 10 mg/kg (0.001, 0.01, or 0.10 mmol/kg); it was not specified if dose was administered by gavage or in diet	multiple doses were given; exposure duration n.p.	The mid and high doses caused changes in conditioned reflexes. The low dose had no effect on conditioned reflexes.	Kagan (1965)
rat (albino; age n.p.)	n.p.	triethylamine, purity n.p.	54.5 mg/kg/day (0.538 mmol/kg/day) (vehicle n.p.)	2 mo; no observation period	No adverse effects were observed.	Dangerous Prop. Ind. Mater. Rep. (1994)

Abbreviations: F = female; M = male; n.p. = not provided

9.1.4.3 Oral Exposure

In male and female albino rats administered 5, 15, 30, or 60 mg (0.05, 0.15, 0.30, or 0.59 mmol) triethylamine by gavage, 3 times/wk for 6 weeks, no adverse effects were observed with the 5- or 15-mg doses, and only slight toxicity was observed with the 30-mg dose (EPA, 1965). Treatment with 60 mg, however, caused convulsions, with females exhibiting the more severe reaction. Mortality was present among female but not male rats. In contrast to this study, no adverse effects were observed in albino rats administered 54.5 mg/kg (0.538 mmol/kg) triethylamine daily for 2 months (Dangerous Prop. Ind. Mater. Rep., 1994).

Administration of multiple doses of 1 or 10 mg/kg (0.01 or 0.10 mmol/kg) triethylamine to albino rats caused changes in conditioned reflexes (duration of exposure not provided) (Kagan, 1965). Administration of a lower dose (0.1 mg/kg; 0.001 mmol/kg) had no adverse effect. It was not specified if the doses were administered by gavage or in the diet.

9.1.5 Chronic Exposure

The studies described in this section are summarized in **Table 6**.

9.1.5.1 Inhalation Exposure

There was a decrease in body weight, changes (not provided) in nervous system function, hypohemoglobinemia, a rise in the number of reticulocytes in blood, and chronic inflammation of lungs in rats (strain and age not provided) exposed to 30-80 mg/m^3 (7.2-19 ppm; 0.30-0.79 mmol/m^3) triethylamine, 3 hours/day for 6 months (Kulagina et al., 1965; cited by Nelson and Bull, 1990).

9.1.5.2 Oral Exposure

Administration of 6 mg/kg (0.06 mmol/kg) triethylamine to rabbits (strain and age not provided) caused a transient effect on hepatic carbohydrate metabolism (Kagan, 1965). Administration of a lower dose (1 mg/kg; 0.01 mmol/kg) had no adverse effect.

9.2 Reproduction and Teratology

The studies described in this section are summarized in **Table 7**.

Table 6. Chronic Toxicity of Triethylamine

Species, Strain, Age	Number and Sex of Animals	Chemical Form, Purity	Dose	Exposure/ Observation Period	Results/Comments	Reference
9.1.5.1 Inhalation Exposure						
rat (strain and age n.p.)	n.p.	triethylamine, purity n.p.	30-80 mg/m^3 (7.2-19 ppm; 0.30-0.79 mmol/m^3), 3 hr/day	6 mo; observation period n.p.	There was a decrease in body weight, changes in nervous system function (n.p.), hypohemoglobinemia, a rise in the number of reticulocytes in blood, and chronic inflammation of lungs.	Kulagina et al. (1965; cited by Nelson and Bull, 1990)
9.1.5.2 Oral Exposure						
rabbit (strain and age n.p.)	exposed: 36 (sex n.p.) controls: n.p.	triethylamine, purity n.p.	1 or 6 mg/kg (0.01 or 0.06 mmol/kg)	7 mo; observation period n.p.	There was a transient effect on hepatic carbohydrate metabolism with the higher dose.	Kagan (1965)

Abbreviations: F = female; M = male; n.p. = not provided

Table 7. Reproductive and Teratological Effects of Triethylamine

Species, Strain, Age	Number and Sex of Animals	Chemical Form, Purity	Dose	Exposure/ Observation Period	Results/Comments	Reference
9.2.1 Embryonic Exposure						
chick embryo (3-day-old White Leghorn)	exposed: 30 eggs per 3 lower doses; 20 eggs for highest dose controls: 100 eggs (vehicle alone)	triethylamine, purity n.p.	0.5, 1.0, 2.0, or 4.0 µmol injected into each egg	single dose; study was terminated 11 days after treatment	The median effective dose (ED_{50}) for embryotoxicity was 0.9 µmol/egg. There was a greater incidence of malformations in triethylamine-treated chicks than in acetone controls (26/110 vs. 1/100 controls), but the occurrence of malformations was not dose dependent. Malformations in triethylamine-treated chicks included changes in eyes, beak, head, gastrointestinal tract, back or neck, and wings, and edema and lymph blebs.	Korhonen et al. (1983a,b)
9.2.2 Oral Exposure						
rat (strain n.p.; 21-day-old)	exposed: 10 M, 10 F per dose controls: 10 M, 10 F	triethylamine, purity n.p.	first and second generation, 2 or 200 ppm in tap water (0.02 or 1.98 mM); third generation, 500 ppm in tap water (4.94 mM)	3 generations	The only adverse effect observed was a slightly reduced average body weight and water consumption in third-generation rats. The quality of the study was compromised by a chronic respiratory disease that affected the colony throughout the experiment.	EPA (1965)
rabbit (pregnant; strain and age n.p.)	n.p.	triethylamine, purity n.p.	n.p.	dose was administered on gestation days 1-3; fetuses were evaluated on day 6	The development of ova into normal blastocysts was disrupted by triethylamine. No other experimental details were given.	Gillner and Loeper (1995)

Abbreviations: n.p. = not provided

9.2.1 Embryonic Exposure

The median effective dose (ED_{50}) for embryotoxicity in 3-day-old White Leghorn chicks was 0.9 µmol triethylamine/egg (Korhonen et al., 1983a, b). Eggs were injected with a single dose of 0.5, 1.0, 2.0, or 4.0 µmol triethylamine and were observed for 11 days. There was a greater incidence of malformations in triethylamine-treated chicks than in acetone controls, but the occurrence of malformations was not dose dependent. Malformations in triethylamine-treated chicks included changes in eyes, beak, head, gastrointestinal tract, back or neck, and wings, and edema and lymph blebs.

9.2.2 Oral Exposure

In a three-generation reproduction study in which male and female rats (strain not provided) were administered triethylamine in drinking water (first and second generation, 2 or 200 ppm [0.02 or 1.98 mM]; third generation, 500 ppm [4.94 mM]), the only adverse effect observed was a slightly reduced average body weight and water consumption in third-generation rats (EPA, 1965). The quality of the study was compromised by a chronic respiratory disease that affected the colony throughout the experiment.

The development of ova into normal blastocysts was disrupted by oral administration of triethylamine to pregnant rabbits (strain not provided) during gestation days 1-3 (dose not provided) (Gillner and Loeper, 1995). Fetuses were evaluated on gestation day 6.

9.3 Carcinogenicity

9.3.1 Human

In a Danish foundry, molders exposed to a variety of chemicals including triethylamine had a significantly increased mortality due to death from bladder cancer, as compared to other skilled workers (Hansen, 1991). Other compounds to which the molders were exposed included

phenol-furan, urea-furan, and urea-phenol-furan resins that all contained an excess of formaldehyde; resole resins; novolak resins to which hexamethylenetetraamine was added; and phenolic-isocyanate resins. The workers were also exposed to emissions and effluents containing carbon monoxide, nitrogen oxides, hydrogen cyanide, ammonia, amines, aldehydes, phenols, benzene, benzoic acid, toluene, cresols, methane, ethylene, acetylene and various polycyclic aromatic hydrocarbons (PAHs). This study was a historical cohort study; workers were followed up for 10 years.

9.3.2 Animal

The study described in this section is summarized in **Table 8**.

No tumors were detected in SIV50 rats (sex and strain not provided) co-administered 0.5% triethylamine hydrochloride (37 mmol/kg feed) and 0.5% nitrite in feed for 1 year (Schweinsberg and Sander, 1972). Triethylamine was not administered as a single compound to any rats.

9.4 Genotoxicity

Studies described in this section are summarized in **Table 9**.

9.4.1 Prokaryotic Mutation Assays

As reported by Zeiger et al. (1987), triethylamine did not induce *his* gene mutations in *Salmonella typhimurium*. Strains TA100, TA98, TA1535, and TA1537 were exposed to doses ranging from 100 to 10,000 µg/plate (0.99-98.82 µmol/plate) using the pre-incubation method in either the presence or absence of 10% rat or hamster liver metabolic activation. The highest nontoxic dose tested was 3333 µg/plate (32.94 µmol/plate).

Ohe (1982) reported that triethylamine pyrolysates (prepared by heating at 600°C for 3 minutes) induced *his* gene mutations in *S. typhimurium.* Strains TA98 and TA100 were exposed

to doses of the triethylamine pyrolysate ranging from 5 to 20 µmol/plate in the presence of rat S9. Pyrolysates prepared at 300°C for 20 minutes, or at 400 or 500°C for 3 minutes were not mutagenic.

9.4.2 *In Vitro* Mammalian DNA Damage Assays

Sorsa et al. (1988) reported that triethylamine did not induce sister chromatid exchanges (SCE) in Chinese hamster ovary (CHO) cells. Cultures were exposed for 4 hours to doses ranging from 70 to 17,900 µM in the presence and absence of rat liver S9. Complete toxicity was observed at 17,900 µM with and without metabolic activation.

9.4.3 *In Vivo* Mammalian Chromosomal Damage

Rats exposed to triethylamine were reported to exhibit a significant increase in aneuploidy but not chromosome breakage in bone marrow (Isakova et al., 1971). Male Wistar rats were exposed to 1 and 10 mg/cm^3 (0.01 and 0.10 mmol/cm^3) triethylamine via continuous inhalation for 30 and 90 days. Fifty to 100 cells were scored per animal. The incidence of cells with

Table 8. Carcinogenicity of Triethylamine

Species, Strain, Age	Number and Sex of Animals	Chemical Form, Purity	Dose	Exposure/ Observation Period	Results/Comments	Reference
rat (SIV50, age n.p.)	F, number n.p.	triethylamine hydrochloride, purity n.p.	0.5% triethylamine hydrochloride (37 mmol/kg) and 0.5% nitrite in feed	1 yr	No tumors were detected. Triethylamine was not administered alone.	Schweinsberg and Sander (1972)

Abbreviations: F = female; n.p. = not provided

Table 9. Genotoxicity of Triethylamine

Test System	Biological Endpoint	S9 Metabolic Activation	Chemical Form, Purity	Dose	Endpoint Response	Comments	Reference
9.4.1 Prokaryotic Mutation Assays							
S. typhimurium strains TA100, TA98, TA1535, and TA1537	*his* reverse gene mutations	-/+ rat or hamster	triethylamine, n.p.	100, 333, 1000, 3333, and 10000 µg/plate (1.0-100 µmol/plate); pre-incubation method	negative/negative	The highest nontoxic dose tested was 3333 µg/plate (33 µmol/plate).	Zeiger et al. (1987)
S. typhimurium strains TA100 and TA98	*his* reverse gene mutations	+	triethylamine pyrolysates, n.p.	5, 10, 15, and 20 µmol/plate pyrolysate (prepared by heating at 300 °C for 20 min. or at 400, 500, or 600°C for 3 min.)	positive	Triethylamine pyrolysates prepared by heating at 600°C for 3 minutes induced *his* gene mutations. Pyrolysates prepared at 300°C for 20 minutes, or at 400 or 500°C for 3 minutes were not mutagenic.	Ohe (1982)
9.4.2 In Vitro Mammalian DNA Damage Assays							
Chinese hamster ovary (CHO) cells	sister chromatid exchange (SCE)	-/+	triethylamine, n.p.	70, 140, 700, 1400, and 17,900 µM for 4 hr	negative/negative	Complete toxicity was observed at 17,900 µM with and without S9.	Sorsa et al. (1988)
9.4.3 In Vivo Mammalian Chromosomal Damage							

Table 8. Carcinogenicity of Triethylamine

Test System	Biological Endpoint	S9 Metabolic Activation	Chemical Form, Purity	Dose	Endpoint Response	Comments	Reference
male Wistar rats	aneuploidy and chromosome breakage	NA	triethylamine, n.p.	1 and 10 mg/cm^3 (0.01 and 0.10 mmol/cm^3) triethylamine via continuous inhalation for 30 and 90 days	negative (chromosome breakage)/ positive (aneuploidy)	Fifty to 100 cells were scored per animal. The incidence of cells with chromosomal breakage did not exceed controls but the incidence of aneuploid cells was significantly higher at 1 mg/cm^3 after 30 days. There was no decrease in mitotic activity.	Isakova et al. (1971)

Abbreviations: NA = not applicable; n.p. = purity not provided

chromosomal breakage did not exceed controls but the incidence of aneuploid cells was significantly higher at 1 mg/cm^3 after 30 days. No decrease in mitotic activity was observed.

9.5 Antigenotoxicity

Hiramoto et al. (1993) reported that triethylamine did not inhibit the induction of DNA damage by the radical initiator, 2,2'-azobis(2-amidinopropane)hydrochloride (AAPH). A mixture of 10 μg/mL supercoiled plasmid pBR322 and 1 mM AAPH with or without 50 mM triethylamine (added as a radical scavenger) was incubated for 3 hrs at 37°C. DNA damage (i.e., DNA single strand breaks) was measured by subjecting the reaction mixture to agarose gel electrophoresis and evaluating the intensity of the unnicked, supercoiled vs. nicked, open circular DNA bands.

9.6 Immunotoxicity

The study described in this section is summarized in **Table 10**.

No adverse effects were observed in female albino mice that had a 1.0% solution of triethylamine in ethanol (72 mM) applied to the skin of the abdomen for 3 days, followed 7 days later by application of a 100% solution of triethylamine to ears for 8 days (Virginia Chemicals, 1987b).

Albino guinea pigs administered a 0.1% triethylamine solution in 0.75% aqueous saline solution (1000 mM) by intracutaneous injection also did not become sensitized. Eight sensitizing doses were given (volume of dose and duration of exposure not provided); challenge doses (number not provided) were given 3 weeks after the last sensitizing dose (Union Carbide, 1958).

9.7 Other Toxic Effects

9.7.1 Effects on Enzyme Activity

Chernen'kii (1968) determined that triethylamine, when tested *in vitro* or *in vivo*, inhibited MAO activity in liver and brain of mice. Based on these and other data, DeBruin (1976) theorized that the toxicity of triethylamine was associated with its ability to competitively inhibit monoamine oxidase (MAO) activity (system not provided). MAO normally catalyzes the deamination of primary, secondary, and tertiary amines (Snyder, 1990; cited by HSDB, 1996).

Triethylamine also significantly inhibits sulfotransferase activity toward dehydroepiandrosterone (DHEA), but not toward cortisol or 2-naphthol, in hepatic cytosolic preparations from adult female Wistar rats (Matsui et al., 1995).

Table 10. Immunotoxicity of Triethylamine

Species, Strain, Age	Number and Sex of Animals	Chemical Form, Purity	Dose	Exposure/Observation Period	Results/Comments	Reference
mouse (albino, 6- to 8-wk-old)	exposed: 10 F controls: 25 F	triethylamine, purity n.p.	induction: 1.0% (v/v) solution in ethanol (72 mM) applied to abdomen on days 1-3 challenge: 100% solution applied to ear on days 10 and 17	17 days; mice were observed for 19 days from start of treatment	There were no adverse effects observed.	Virginia Chemicals (1987b)
guinea pig (albino; age n.p.)	exposed: 20 M controls: 0	triethylamine, purity n.p.	0.1% triethylamine solution in 0.75% aqueous saline solution (1000 mM) (volume of dose n.p.)	8 sensitizing doses were given by intracutaneous injection (duration n.p.); challenge doses (number n.p.) were given by intracutaneous injection 3 wk after last sensitizing dose	The guinea pigs did not become sensitized.	Union Carbide (1958)

Abbreviations: M = male; n.p. = not provided

In male Fischer 344 rats, triethylamine did not inhibit the *N*-oxidation of azomethane to azoxymethane, an essential step in the metabolic activation of 1,2-dimethylhydrazine to a carcinogen (Fiala et al., 1977). Rats were administered 1.1 mmol/kg triethylamine by gavage, followed 2 hours later by s.c. injection of 21 mg/kg 1,2-dimethylhydrazine.

9.7.2 Effects on Cellular Protein Content

Triethylamine inhibited protein degradation and induced lysosomal swelling (vacuolation) in isolated hepatocytes from male Wistar rats (Seglen and Gordon, 1980). In nutrient-free medium, triethylamine also inhibited protein synthesis in hepatocytes.

A concentration of 7.3 mM triethylamine produced a 50% reduction in protein content (PI_{50}) in cultured Hep G2 cells after 24 hours (Dierickx, 1989).

9.7.3 Intercellular Communication

Chen et al. (1984) concluded that triethylamine did not inhibit gap junction intercellular communication in Chinese hamster V79 cells. Co-cultures of wild type (thioguanine sensitive, HGPRT+) and mutant (thioguanine resistant, HGPRT-) cells were exposed for 3 days to triethylamine (dose levels not provided) and 10 µg/mL 6-thioguanine in the absence of metabolic activation.

10.0 STRUCTURE-ACTIVITY RELATIONSHIPS

No data were found on structure-activity relationships.

11.0 ONLINE DATABASES AND SECONDARY REFERENCES

11.1 Online Databases

Chemical Information System Files

TSCATS (Toxic Substances Control Act Test Submissions)

Internet Databases

Code of Federal Regulations full text. 1996 versions of various titles via GPO Gate, a gateway by the Libraries of the University of California to the GPO Access service of the Government Printing Office, Washington, DC. Internet URL http://www.gpo.ucop.edu/

National Library of Medicine Databases

EMIC and EMICBACK (Environmental Mutagen Information Center)

STN International Files

BIOSIS (Biological Abstracts)
CA File (Chemical Abstracts)
CANCERLIT
CEN (Chemical & Engineering News)
CIN (Chemical Industry Notes)
CSNB (Chemical Safety News Base)
EMBASE (Excerpta Medica)
HSDB (Hazardous Substances Data Bank)
IPA (International Pharmaceutical Abstracts)
MEDLINE (Index Medicus)
RTECS (Registry of Toxic Effects of Chemical Substances)
TOXLINE
TOXLIT

TOXLINE includes the following subfiles:

Toxicity Bibliography	TOXBIB
International Labor Office	CIS
Hazardous Materials Technical Center	HMTC
Environmental Mutagen Information Center File	EMIC
Environmental Teratology Information Center File (continued after 1989 by DART)	ETIC
Toxicology Document and Data Depository	NTIS

Toxicology Research Projects	CRISP
NIOSHTIC7	NIOSH
Pesticides Abstracts	PESTAB
Poisonous Plants Bibliography	PPBIB
Aneuploidy	ANEUPL
Epidemiology Information System	EPIDEM
Toxic Substances Control Act Test Submissions	TSCATS
Toxicological Aspects of Environmental Health	BIOSIS
International Pharmaceutical Abstracts	IPA
Federal Research in Progress	FEDRIP
Developmental and Reproductive Toxicology	DART

11.2 Secondary References

Chemcyclopedia 97, Strum, K., Ed. Vol. 15 American Chemical Society, Washington D.C.

CRC Handbook of Chemistry and Physics, Weast, R.C., and M.J. Astle, Eds. CRC Press, Boca Raton, FL, 1980.

Documentation of the Threshold Limit Values and Biological Exposure Indices, American Conference of Governmental Industrial Hygienists, Cincinnati, OH., 1986.

The Federal Environmental & Safety Authority (FESA), CD-ROM with quarterly updates of the Federal Guidelines. CPI Electronic Publishing, Scottsdale, AZ. Last updated February, 1997.

Kirk-Othmer Encyclopedia of Chemical Technology, 2nd ed., A.E. Schweizer, R.L. Fowlkes, J.H. McMakin, and T.E. Whyte, Jr., Eds., A Wiley-Interscience Publication, John Wiley & Sons, New York, NY. 1978. Listed in Section 12 as Schweizer, et al. (1978).

Patty's Industrial Hygiene and Toxicology, 3rd ed., D.H. Clayton and F.E. Clayton, Eds., Vol. 2B, A Wiley-Interscience Publication, John Wiley & Sons, Inc., New York, NY. 1981. Listed as Beard and Noe (1981) in Section 12.

Sax's Dangerous Properties of Industrial Materials, 8thed. Vol. 11., R.L. Lewis, Jr. Ed., Van Nostrand Reinhold, New York, NY 1992. Listed in Section 12 as Lewis (1992).

SRI Directory of Chemical Producers, SRI International, Menlo Park, CA, 1996. Listed in Section 12 as SRI Int. (1996).

Threshold Limit Values for Chemical Substances and Physical Agents. Biological Exposure Indices, American Conference of Governmental Industrial Hygienists, Cincinnati, OH., 1996. Listed in Section 12 as ACGIH (1996).

12.0 REFERENCES

ACGIH. 1986. American Conference of Governmental Industrial Hygienists Inc. Documentation of the Threshold Limit Values and Biological Exposure Indices. 5th ed.

Air Products & Chemicals, Inc. 1976a. Primary Skin Irritation Study of N,N-Diethylethanamine in Rabbits. U.S. EPA/OTS Public Files, Document No. 860870001492, Fiche No. 0515654.

Air Products & Chemicals, Inc. 1976b. Acute Inhalation Toxicity of N-Butyl-1-Butanamine in Rats. U.S. EPA/OTS Public Files, Document No. 86-870001493, Fiche No. 0515655.

Åkesson, B., and S. Skerfving. 1990. Effects of Ethanol Ingestion and Urinary Acidity on the Metabolism of Triethylamine in Man. Int. Arch. Occup. Environ. Health 62(1):89-93.

Åkesson, B., I Floren, and S. Skerfving. 1985. Visual Disturbances After Experimental Human Exposure to Triethylamine. Br. J. Ind. Med. 42(12):848-50.

Åkesson, B., M. Bengtsson, and I. Floren. 1986. Visual Disturbances After Industrial Triethylamine Exposure. Int. Arch. Occup. Environ. Health 57(4):297-302.

Åkesson, B., S. Skerfving, and L. Mattiasson. 1988. Experimental Study on the Metabolism of Triethylamine in Man. Br. J. Ind. Med. 45:262-268.

Åkesson, B.V., S. Skerfving, B. Stahlom, and T. Lundh. 1989a. Metabolism of Triethylamine in Polyurethane Foam Manufacturing Workers. Am. J. Ind. Med. 16(3):255-65.

Åkesson, B., E. Vinge, and S. Skerfving. 1989b. Pharmacokinetics of Triethylamine and Triethylamine-*N*-oxide in Man. Toxicol. Appl. Pharmacol. 100:529-538.

Amoore, J. E., and E. Hautala. 1983. Odor as an Aid to Chemical Safety: For Thresholds Compared With Threshold Limit Values and Volatilities for 214 Industrial Chemicals in Air and Water Dilution. JAT, J. Appl. Toxicol. 3(6):272-90.

Arbetsmiljö. 1989. Abstract of New Research Brings Down TLV for Triethylamine. Arbetsmiljö 7:8.

Ashland Chemical Co. 1970. Comparative Toxic Effects of Exposure of Male Rats to Vapors of Dimethyl Ethyl Amine and Triethylamine with cover letter Dated 072287. U.S. EPA/OTS Public Files, Document No. 86-870001308, Fiche No. 0515467.

Ashland Chemical Co. 1986. Monitoring Surveys - N,N-Diethylethanamine, Isopropanol, Butanol, Methanol, Acetone, Hexane and Toluene. U.S. EPA/OTS Public Files, Document No. 86-870001686, Fiche No. 0515762.

BASF Corporation. 1995. IUCLID Data Sheet for triethylamine.

Beard, R.R., and J.T. Noe. 1981. Aliphatic and Alicyclic Amines. In: D.G. Clayton and F.E. Clayton, Eds,. Patty's Industrial Hygiene and Toxicology, 3rd ed. Vol. 2B. A Wiley-Interscience Publication. John Wiley and Sons, New York, NY, pp. 3135-3173.

Brieger, H., and W.A. Hodes. 1951. Toxic Effects of Exposure to Vapors of Aliphatic Amines. AMA Arch. Ind. Hyg. Occup. Med. 3:287-291.

Budavari, S., Ed. 1996. The Merck Index, 12th ed. Merck & Co., Inc., Whitehall, NJ.

Carpenter, C.P., H.F. Smyth, Jr., and C.B. Shafer. 1948. The Acute Toxicity of Ethylene Imine to Small Animals. J. Ind. Hyg. Toxicol. 30:2-6.

Chen, T.H., T.J. Kavanagh, C.C. Chang, and J.E. Trosko. 1984. Inhibition of Metabolic Cooperation in Chinese Hamster V79 Cells By Various Organic Solvents and Simple Compounds. Cell Biol. Toxicol. 1(1):155-171.

Chernen'kii, I.K. 1968. Mechanism of Triethylamine Toxicity. Farmakol. Toksikol 31(6):750-2.

Conrard, R. 1977. Cold-Box Coremaking - Ashland Process. Cahiers De Notes Documentaires - Securite Et Hygiene Du Travail 87:195-203.

Dangerous Prop. Ind. Mater. Rep. 1994. Chemical Review of Triethylamine. Dangerous Prop. Ind. Mater. Rep. 14(1):2-27.

DeBruin, A. 1976. Biochemical Toxicology of Environmental Agents. Elsevier/North-Holland Biomedical Press, Amsterdam, p. 1052.

Dierickx, P.J. 1989. Cytotoxicity Testing of 114 Compounds by the Determination of the Protein Content in Hep G2 Cell Cultures. Toxicol. In Vitro 3(3):189-93.

EPA. 1965. U.S. Environmental Protection Agency, Office of Saline Water. Toxicity of Triethylamine to Albino Rats (Final Report). Document No. 86-870000536, Fiche No. OTS0513614.

Fiala, E.S., G. Bobotas, C. Kulakis, L.W. Watterberg, and J.H. Weisburger. 1977. Effects of Disulfiram and Related Compounds on the Metabolism In Vivo of the Colon Carcinogen 1,2-Dimethylhydrazine. Biochem. Pharmacol. 26(19):1763-1768.

Gagnaire, F., S. Azim, P. Bonnet, P. Simon, J.P. Guenier, and J. de Ceaurriz. 1989. Nasal Irritation and Pulmonary Toxicity of Aliphatic Amines in Mice. J. Appl. Toxicol. 9(5):301-304.

Gillner, M, and I. Loeper. 1995. Health Effects of Selected Chemicals. 3. Triethylamine. Nord 28:193-209. TOXLINE Abstract No. 96:83111.

Golovnya, R.V., I.L. Zhuravleva, and J. Kapustin. 1979. Gas Chromatographic Analysis of Volatile Nitrogen Bases of Boiled Beef as Possible Precursors of *N*-Nitrosamines. Chem. Senses Flavour 4:97-105.

Hansen, M.K., M. Larsen, and K. Cohr. 1987. Waterborne Paints: A Review of Their Chemistry and Toxicology and the Results of Determinations Made During Their Use. Scand. J. Work. Environ. Health 13:473-485.

Hansen, E.S. 1991. Cancer Mortality Among Danish Molders. Am. J. Ind. Med. 20(3):401-410.

Hiramoto, K., H. Johkoh, K.I. Sako, and K. Kikugawa. 1993. DNA Breaking Activity of the Carbon-Centered Radical Generated From 2,2N-Azobis(2-Amidinopropane) Hydrochloride (AAPH). Free Rad. Res. Comms. 19(5):323-332.

Hoechst Celanese Corp. 1989. Dermal Corrosivity Study in Rabbits with C-01043 Triethylamine (IMO) with attachments and cover letter dated 021390. U.S. EPA/OTS Public Files, Document No. 86-000000098, Fiche No. 0522354.

HSDB. 1996. The Hazardous Substances Data Bank. Online database produced by the National Library of Medicine.

Isakova, G.K., B.Y. Ekshtat, and Y.Y. Kerkis. 1971. On Studies of the Mutagenic Properties of Chemical Substances in the Establishment of Hygienic Standards. Hyg. Sanit. 36(11):178-184.

Kagan, G.Z. 1965. The Determination of the Maximum Permissible Concentrations of Diethylamine and Triethylamine in Bodies of Water. Hyg. Sanit. 30:351-356.

Kay, R. W. 1974. Survey into the Fumes Evolved From Foundry Sand Binders Based on Synthetic Resins. Brit. Foundryman 67:1-4.

Kelly, T.J., R. Mukund, C.W. Spicer, and A.J. Pollack. 1994. Concentrations and Transformations of Hazardous Air Pollutants. Environ. Sci. Technol. 28(8):378a-387a.

Korhonen, A., K. Hemminki, and H. Vainio. 1983a. Toxicity of Rubber Chemicals Towards Three-day Chicken Embryos. Environ. Health 9(2):115-19.

Korhonen, A., V. Hemminki, and H. Vainio. 1983b. Embryotoxicity of Sixteen Industrial Amines to the Chicken Embryo. J. Appl. Toxicol. 3(2):112-17.

Lewis, R.J., Sr. 1992. Sax's Dangerous Properties of Industrial Materials. 8th ed. Vol. III. Van Nostrand Reinhold, New York.

Lynch D.W., W.J. Moorman, T.R. Lewis, P. Stober, R.D. Hamlin, and R.L. Schueler. 1990. Subchronic Inhalation of Triethylamine Vapor in Fischer-344 Rats: Organ System Toxicity. Toxicol. Ind. Health 6(3-4):403-14.

MacBain, G., and R.C. Strange. 1983. Foundries. Encyc. Occup. Health Saf., pp. 916-923.

Matsui, M., M. Takahashi, Y. Miwa, W. Motoyoshi, and H. Homma. 1995. Structure-Activity Relationships of Alkylamines That Inhibit Rat Liver Hydroxysteroid Sulfotransferase Activities In Vitro. Biochem. Pharmacol. 49(5):739-741.

Nelson, M.A., and R.J. Bull. 1990. Triethylamine. Ethyl Browning's Toxicity and Metabolism of Industrial Solvents, 2nd ed. Vol. 2: Nitrogen and Phosphorus Solvents. D.R. Buhler and D.J. Reed, Ed. Elsevier Science Publishers B. V., Netherlands.

Nielson, G.D. and M. Yamigiwa. 1989. Structure-Activity Relationships of Airway Irritating aliphatic amines. Receptor Activation Mechanisms and Predicted Industrial Exposure Limits. Chem.-Biol. Interactions 71:223-244.

NIOSH. 1984. National Institute for Occupational Safety and Health. National Occupational Exposure Survey (1980-1983). Cincinnati, OH: Department of Health, Education, and Welfare.

NIOSH. 1997. Triethylamine [TEA] (121-44-8). Evaluation sheet prepared as a background NIOSH summary for the ICCEC meeting in August 1991.

Ohe, T. 1982. Mutagenicity of Pyrolysates From Guanidine, Ureide, Secondary Amines and Polyamines Found By the *Salmonella*/Mammalian-Microsome Test. Mutation Res. 101:175-187.

Otson, R., P. Fellin, and Q. Tran. 1994. VOCs in Representative Canadian Residences. Atmos. Environ. 28(22):3563-9.

Pennwalt Corp. 1986. Eye Irritancy in Rabbits using Triethylamine (Final Report). U.S. EPA/OTS Public Files, Doc. No. 86-870000535, Fiche No. 0513613.

Potts, A.M., R.R. Rouse, R.A. Eiferman, and P.C. Au. 1986. An Unusual Type of Keratopathy Observed in Polyurethane Workers and its Reproduction in Experimental Animals. A. J. Ind. Med. 9(2):203-213.

Reilly, M.J., K.D. Rosenman, J.H. Abrams, Z.Zhu, C. Tseng, V. Hertzberg, and C. Rice. 1995. Ocular Effects of Exposure to Triethylamine in the Sand Core Cold Box of the Foundry. Occup. Environ. Med. 52(5):337-343.

RTECS. 1996. Registry of Toxic Effects of Chemical Substances. Online database produced by National Institute of Occupational Safety and Health.

Schueler, R.L. 1984. Report of Pathologic Findings in Fischer 344 Rats Exposed by Inhalation to Allylamine, Ethylamine, Diethylamine, and Triethylamine. Unpublished report prepared by

Research Pathology Associates, Inc. for Dr. David Groth, DHHS PHS CDC, NIOSH, Robert A. Taft Labs, 4676 Columbia Pkwy., Cincinnati, OH 45226. NIOSH Contract No. 211 83 0020.

Schweinsberg, F., and J. Sander. 1972. Carcinogenic Nitrosamines From Simple Aliphatic Tertiary Amines and Nitrite. Hoppe-Seyler's Z. Physiol. Chem. 353(11):1671-1676.

Schweizer, A.E., R.L. Fowlkes, J.H. McMakin, and T.E. Whyte, Jr. 1978. Aliphatic Amines. Kirk-Othmer Encycl. Chem. Technol. 2nd ed. 2:272-83.

Seglen, P.O., and P.B. Gordon. 1980. Effects of Lysosomotropic Monoamines, Diamines, Amino Alcohols, and Other Amino Compounds on Protein Degradation and Protein Synthesis in Isolated Rat Hepatocytes. Mol. Pharmacol. 18(3):468-75.

Smyth, H.F., C.P. Carpenter, and C.S. Weil. 1951. Range-Finding Toxicity Data: List IV. Arch. Ind. Hyg. Occup. Med. 4:119-122.

Sorsa, M., L. Pyy, S. Salomaa, L. Nylund, and J.W. Yager. 1988. Biological and Environmental Monitoring of Occupational Exposure to Cyclophosphamide in Industry and Hospitals. Mutation Res. 204:465-479.

SRI Int. 1996. SRI Directory of Chemical Producers, United States, 1996. SRI International, Menlo Park, CA.

SRI Int. 1997. Alkylamines. Section Heading: United States, Consumption, Ethylamines, Triethylamine. Chemical Economics Handbook, online version, DIALOG File 359. Produced by SRI International, Menlo Park, CA.

Strum, K., Ed. 1997. Chemcyclopedia 97, Vol. 15. American Chemical Society, Washington, D.C.

Tkachev, P.G. 1970. Hygienic Assessment of the Effect of Inhalation of Small Concentrations of Aliphatic Ethylamines. Hyg. Sanit. 35.

Union Carbide Corp. 1949. Range Finding Tests on Triethylamine. U.S. EPA/OTS Public Files, Document No. 86-870001409, Fiche No. 0515571.

Union Carbide Corp. 1958. Sensitization by the Intracutaneous Method of Triethylamine in Guinea Pigs. U.S. EPA/OTS Public Files, Document No. 86-870001424, Fiche No. 0515586.

Union Carbide Corp. 1979. Range Finding Toxicity Studies of Triethylamine. U.S. EPA/OTS Public Files, Document No. 86-870001448, Fiche No. 0515610.

Union Carbide Corp. 1986. Initial Submission: Primary Dermal Irritation Study of Ethylamine, Triethylamine, and Diethylamine in Albino Rabbits with Cover Letter dated 072892. U.S. EPA/OTS Public Files, Document No. 88-920004593, Fiche No. 0537574.

Virginia Chemicals. 1987a. Acute Dermal Toxicity of Triethylamine in Rabbits. U.S. EPA/OTS Public Files, Document Number: 86-870000815, Fiche No.OTS0515253.

Virginia Chemicals. 1987b. Mouse Ear Swelling Test (Sensitization Assay) of Triethylamine. U.S. EPA/OTS Public Files, Document No. 86-870000817, Fiche No.OTS0515255.

Warren, D. W. Jr. and D.F. Selchan. 1988. An Industrial Hygiene Appraisal of Triethylamine and Dimethylamine Exposure Limits in the Foundry Industry. Am. Ind. Hyg. Ass. J. 49(12):630-4.

Warren, D.W., and D.F. Selchan. 1988. An Industrial Hygiene Appraisal of Triethylamine and Dimethylethylamine Exposure Limits in the Foundry Industry. Am. Ind. Hyg. Assoc. J. 49(12):630-634.

Weast, R.C., and M.J. Astle, Eds. 1980. CRC Handbook of Chemistry and Physics. CRC Press, Inc. Boca Raton, FL.

Zeiger, E., B. Anderson, S. Haworth, T. Lawlor, K. Mortelmans, and W. Speck. 1987. Salmonella Mutagenicity Tests: III. Results From the Testing of 255 Chemicals. Environ. Mutagen. 9(Suppl. 9):1-110.

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